Effects of Attention on The Intensity of Cutaneous Pressure and on Visual Brightness

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EFFECTS OF ATTENTION ON THE INTENSITY OF CUTANEOUS PRESSURE AND ON VISUAL BRIGHTNESS

BY

SIDNEY M. NEWHALL, Ph. D.

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SUMMARY

I. Introduction, the problem and the point of departure. (pp. 5-7)

II. Experiments concerned with the effect of attention on comparison of successive and of simultaneous superthreshold areal pressures; and on approximately threshold areal pressure. The stimulus-factors which the pressure-balance aims to control are enumerated, the apparatus is described, and the physical and introspective aspects of the pressure are discussed. (pp. 9-21)

Under the experimental conditions:

(a) There is a marked tendency to underestimate the second of two brief, successive, areal pressures, occurring on the same cutaneous area. (pp. 21-27). It is suggested that the underestimation may be ascribable to sensory fatigue due to the first pressure. (pp. 45-46)

(b) When two brief areal pressures occur simultaneously on the finger-berries of the left and right middle-fingers, respectively, and attention is directed to a given hand; the judgments in general indicate a relative increase in the intensity of the pressure corresponding to the hand attended to. (pp. 29-38, 46)

(c) When an approximately threshold areal stimulus is presented after different prestimulus situations which favor respectively different degrees of attention at the time of presentation, the number of stimuli judged superthreshold tends to vary directly with the presumptive degree of attention. (pp. 38-45, 46)

6 Feb. 1952

III. Experiments concerned with the effect of attention on brightness when the stimulus is at approximately the difference-threshold. The exposure apparatus is described and the physical and introspective aspects of the stimulus are discussed. (pp. 47-55)

Under the experimental conditions:

(a) When an approximately difference-threshold, momentary visual stimulus is presented after different prestimulus situations which favor respectively different degrees of attention at the time of presentation, the number of stimuli judged superthreshold shows a weak tendency to vary with the presumptive degree of attention. Further, there is a tendency for the degree of momentary visual brightness to vary in accordance with the presumptive degree of attention. (pp. 55-62, 69-71)

40919

SUMMARY—CONTINUED

(b) If series of five momentary visual stimuli whose physical value is uniform and approximately at the difference-threshold, are presented simultaneously with five clicks; there occurs the dual tendency for more of the visual stimuli to be judged superthreshold and the brightness of greater magnitude, than in series where the clicks are omitted. (pp. 62-69). It is suggested that the clicks may contribute to a higher degree of attention, and that to the latter may be due the greater number of stimuli judged superthreshold and the greater brightness, when the clicks are used. (p. 71)

IV. It is apparently a justifiable conclusion that, in general, attention increases the intensity of moderate and liminal areal pressures, and the degree of moderate visual brightness when the latter is near the difference-limen. (p. 73). A theoretical construction is given for the purpose of synthesizing the results appearing to bear upon the thesis. (pp. 73-75)

Effects of Attention on the Intensity of Cutaneous Pressure and on Visual Brightness

I. INTRODUCTION

The main problem of the experimental investigation reported in this paper concerns the effect of attention on intensity of sensory experience. The present study is the continuation of an investigation which commenced in audition.[1] The principal findings of the latter may be briefly resumed as follows: (1) Attention can modify the intensity of auditory sensation.[2] (2) Attention appears to have the greatest effect when the absolute intensity of the sensation is low.[3] (3) The effect is a relative increase in the intensity of the component attended to, which seemed to be due to absolute decrease in the component abstracted from. This interpretation of the meaning of the apparent increase is only partially borne out by the results of the present experiments in pressure and vision which seem to indicate, as stated later, both absolute and relative increase in intensity of the sensory experience attended to.

It was noted at the time of the earlier study that while our conclusions pointed to change in relative intensity of auditory sensation due to attention,[4] analogical reasoning from sense-field to sense-field would be unsafe. This, together with the controversial status of the problem and its theoretical importance, constitutes the stimulus for the present investigation.

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[1] Newhall, S. M.; The Modification of the Intensity of Sensation by Attention, Jour. Exp'l. Psychol., 1921, 4, 227-243.

[2] For the assumption upon which these conclusions rest, cf. the original paper, p. 228.

[3] Ibid, 235.

[4] The chief auditory results are apparently confirmed by the subsequent investigation of Maria Kiefer: Experimentelle Untersuchung über die quantitativen und qualitativen Beziehungen der monauralen und binauralen Schalleindrücke, sowie deren Verwertung zur Deutung des Weber-Fechnerschen Gesetzes. Archiv f.d. ges. Psychol., 1922, 42, 185-220. Cf. esp. 210, 217, 218.

Partly because there is still disagreement regarding the connotation of attention, and partly because of the apparently numerous aspects of the process capable of study, it is desirable to notice the nature of our own point of departure. In common with the tradition of the Wesleyan Laboratory, our point of departure has been dynamic. With respect to method, we have sought the conditions of the facts by any method that seemed applicable, either introspective or behavioristic. With respect to the nature of the facts of mental life, we have proceeded from the standpoint of a physiological psychology.

While it is furthest from our intention to appear to take sides in a matter still at issue, we must obviously make some delimitation of the meaning of attention to us; and so "it will be assumed that attention is a psychophysical process, the intimate nature of which is still in doubt, but which is known by certain of its functions. By a function of attention is meant something which varies whenever attention varies."[5]

Clearness and the reduction of the field of consciousness are held to be functions of attention. It is conceivable that sensory intensity may vary through a certain range according to attention. Indeed, efforts have been made to measure the degree of attention on the basis of liminal intensities, and therefore under the assumption that intensity near the limen varies with attention.[6]

With regard to pressures and brightnesses in our experiments, there is intended no implication that we are dealing with the attributes of pure sensations. It is extremely doubtful if such are ever given in experience. It is believed, however, that the processes have been kept relatively simple experimentally. In the experiments with varying pressure, we are undoubtedly dealing with intensity-differences. In varying brightness we may or may not be dealing with a mere matter of intensity. But regardless of any final decision concerning the qualitative or quantitative nature of the brightness-series, our experimental investigation concerns itself directly and simply with brightness changes.

Two criteria of change effected by attention have been employed. Adequate control being assumed, a change in the intensity of pressure, or in visual brightness accompanying attention to the sensation, would be presumptively due to attention. Second, if a stimulus should pass the limen in one direction or the other when attention is directed to the sensation and not do so otherwise, the change would be a presumptive effect of attention. The experiments were made with the above considerations in mind.

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[5] Woodrow, H.: The Measurement of Attention, Psychol. Monog., 1914, 17. (No. 76), 6.

[6] Cf. Citations of Geissler: The Measurement of Attention. Am. Jour. Psych. 1909, 20, 489, 495-6.

An extensive citation of literature of the general problem is not made here. A recent brief historical summary, together with an indication of sources, is to be found in a previous paper.[7]

The experiments were performed during the academic year 1921-2, November to April inclusive, in the Psychological Laboratory of Wesleyan University. The four observers who participated were, Professor Raymond Dodge (D), Mr. J. S. Foster (F), Mr. R. W. Walter (W), and the writer (N).[8] The latter was experimenter in all series except those in which he himself was observer, when D was experimenter. Observers F and W were college seniors, specializing in psychology, and with a year's experience in observation in connection with an attentional problem. They worked without knowledge of the significance to the thesis of the particular questions upon which their judgments were given. We made sure on this point by questioning the observers at the end, and not until the end, of all the experiments. N had had over two years of observational experience. D and N obviously worked with knowledge of the problem.

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[7] Op. cit., 223-7.

[8] The locus of the experimental work was the Wesleyan Laboratory instead of the Columbia Laboratory by special arrangement between the Laboratories, with the advice and consent of Professor R. S. Woodworth of Columbia. The writer takes this opportunity of recording his indebtedness to the observers, and especially to Professor Dodge who gave advice and aid throughout the investigation, and to Professor Woodworth for his criticism of a Seminary report.

II. EXPERIMENTATION IN THE FIELD OF PASSIVE PRESSURE

The pressure experiments are concerned with the effect of attention on comparison of successive and of simultaneous superthreshold pressures; and on approximately liminal pressure. The task in general consists, on the one hand, in the comparison of pressure-intensities, one of which is more closely attended to than the other; and on the other hand, in the observation of near-liminal pressure under varying conditions of attention.

The two obvious technical problems were those of controlling attention and the stimulus. The difficult problem of the control and measurement of attention is of great psychophysical importance, and already has a considerable history; for it is something which every investigator of attention must face.[9] The difficulty was no less real in the present than in prior investigations. Three main methods were employed for varying the degree of attention, i.e., the single-task method, the double-task method, and the method of Woodrow, in which the change in attention is produced by modifying one of its conditions.[10]

As in the closely related research of Mitchell,[11] no attempt was made to measure precisely either attention or the effect of the distractor or detractor on a known attentional function. The problem does not require it. But as will be evident later, our experimental technique provided real differences in attention. The details of the methods used will be given in connection with the particular experimental series to which they appertain. While the apparatus for producing the pressure stimuli was developed during the course of the experiments, it will be described presently, for purposes of expository clearness, as in its most complete form; and references to the developmental changes will be made in appropriate places.

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[9] Wirth, Geissler, Woodrow, Dallenbach, and other experimentalists interested in attention, have published work on this problem. F. E. Moyer believed that he was the first to publish a study "of the actual workings of a distraction." Cf., A Study of Certain Methods of Distracting the Attention. Am. Jour. Psychol., 1896-7, 8, 405-413.

[10] On the first two methods see Geissler, L. R.: op. cit., 485-491; and on the third method, Woodrow, H., op. cit. 154-7.

[11] Mitchell, D.: The Influence of Distractions on the Formation of Judgments in Lifted Weight Experiments. Psychol. Monog. 1914, 17. (No. 74) pp. 58., cf. p. 2.

The Pressure-Balance and the Characteristics of the Stimulus

Numerous investigations of the cutaneous sense have demonstrated that the physical conditions of stimulation are complex. The various factors involved in the constitution of a pressure stimulus which the present apparatus aimed to control are as follows: (1) the area of contact, (2) the nature of the surface, (3) the form of the area, (4) its temperature, (5) its position on the skin, (6) the initial weight, (7) the stimulus weight, (8) its speed of onset, (9) the form of the curve of onset with its time relations and the magnitude of cutaneous depression, (10) the release of pressure. The description of the apparatus gives the various means which were used in controlling the above factors. Since our apparatus is of original design and construction, detailed treatment may be useful.[12]

It is (Fig. 1) of the balanced beam type:[13] the stimulus is presented by briefly varying the downward pressure upon the epidermis of a contact object which is attached to the beam

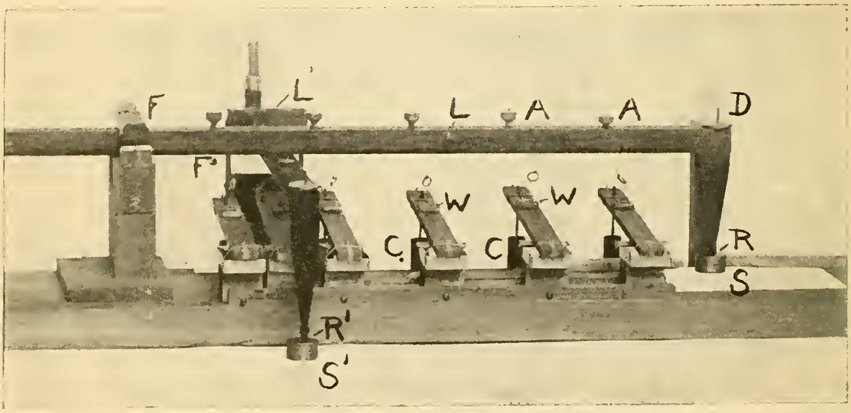

Fig. 1

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[12] As far as we know the apparatus which it most resembles is that described by Cook, H. D., and v. Frey, M.: Der Einfluss der Reizstärke auf den Wert der simultanen Raumschwelle der Haut. Zeitschrift für Biologie., 1911, 56, 539-541. It varies from this apparatus of von Frey in the more accurate control of the form of onset curve, as well as in the provision for minimizing the stimulus value of the release.

[13] Pressure apparatus of the beam or lever type has, e.g., been described by von Frey, M.: Untersuchungen über die Sinnesfunctionen der Menschlichen Haut., Abh. der math.-physischen Classe der Königl. Sächsischen Gesellschaft der Wissenschaften. 1896, Bd. 23, 3, S. 189.; and by Pauli R.: Ein neuer Reizhebel für sukzessive und simultane Erregung von Druckpuncten. Zeitschrift für Biologie, 1912, 59, Neue Folge 41, 420-5.

or stimulus lever, L.[14] This variation is accomplished by changing the downward force acting upon the stimulus lever. The contact object, R, used throughout the reported experiments, (and pictured resting on a short metal cylinder) consisted of a smooth, hard rubber cylinder 5 mm. in diameter and about 17 mm. in length. In preliminary experiments, aiming to discover a contact suitable to our purpose, circular areas of 1 mm. and 3 mm. diameter were also used.

The cylinder was turned down (in a lathe) from one end for a distance of one cm. to form a shoulder. The part of smaller diameter thus formed was then pushed tightly up to the shoulder into a vertical hole bored in the blunt apex of a slender inverted pyramid, which is itself rigidly attached to the end of the stimulus lever, L. The hole was so bored as to bring the area of contact directly below the pin near D.

The sharp circular edge of the contact area was smoothed very slightly. Since rubber is a poor heat conductor, the area of contact readily assumed the temperature of the epidermis upon which it rested. The smooth surface of the stage, S, below the contact and upon which the observer's fingers rest is covered by white paper. Paper also is a poor conductor of heat. The second contact object, R′, used with R in simultaneous presentation, is similar to R in form and material. It is, like R, mounted in a slender pyramidal block; and the latter is rigidly attached to the end of a second stimulus lever, L′, which crosses L perpendicularly and below.

The stimulus levers are of approximately the same form and each of a mass of 300 g. While they are of different lengths—L being 69 cm. and L′ 41 cm. overall—the fulcrums, F and F′, are at relatively the same positions with reference to length. These precautions were taken for the purpose of eliminating possibly disturbing inertia differences depending upon the magnitude and distribution of the masses. Each lever is mounted in knife-edge bearings, F and F′. The knife edges are slightly nicked to reduce lateral movement of the levers. The shorter arms are counterbalanced to such a degree that the freely swinging levers will come to rest in horizontal positions (as represented in the figure). The clearance at the crossing is about 3 mm.

Under these circumstances the vertical distances between the contact areas and the respective stages, S and S′, are approximately equal to the dorso-ventral diameters of the fingers which are placed in position for stimulation—fingerberry uppermost. (The figure shows short metal cylinders in place of fingers.) With the levers in balance (as represented), there would therefore be an initial downward pressure of approximately zero. The initial or constant pressure upon the finger, to which the stimulus pressure is briefly added and then subtracted, is 10 g. produced by placing the 10 g. brass disc, D, upon the pin. In some of the experiments a 20 g. disc was employed. In preliminary experiments aiming to discover a satisfactory initial weight, 40, 60, and 80 g. discs were also tried. The initial weight tends to insure constancy of the cutaneous area stimulated during a series by reducing slight accidental slips of the finger.

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[14] Capital letters correspond to the letters in Fig. I.

The length of the longer stimulus lever, L, from the pin, a point directly over the contact area, to the fulcrum, F, is 48 cm. Along this arm five 10 g. lead weights, W, are suspended on heavy threads at 8 cm. intervals. The upper end of each thread passes through a vertical hole in the stimulus lever and is attached to an adjustment screw, A. The lower end is attached to a Goodrich No. 6 rubber band, showing as a little ring in the figure, which in turn is slipped into the hooked end of the pin which rises from the center of the stimulus weight proper. Four No. 6 rubber bands, crossing each other in pairs, are slipped around each weight to prevent contact noises.

The weights, which are numbered for convenience from 1 to 5, left to right, rest each on what we will call a releasing lever, at the mid-position of the longer arm. The latter is upheld against gravity by means of a Goodrich No. 8 rubber band which pulls downward on the shorter arm as seen in the foreground of Fig. I. The length of the suspension of each lead weight is so adjusted by turning the corresponding screw, A, that when both the stimulus lever and the releasing lever are horizontal the weight barely clears the releasing lever-arm. In making this adjustment, an index mounted on an upright just behind the end of the stimulus lever indicates whether or not L is horizontal. A spirit level was used on the releasing levers for the same purpose.

With this adjustment, sufficient depression of a releasing lever will cause the corresponding weight to clear, and consequently increase the pressure at the area of contact. Since the five 10 g. weights hang at distances from the fulcrum of respectively 1/6, 2/6, 3/6, 4/6, and 5/6 of the distance to the area of contact, each adds when hanging free to the initial pressure at the area of contact respectively 1.66, 3.33, 5.00, 6.66, and 8.33 g.

It is commonly recognized that the speed of onset of a pressure stimulus is a significant factor in its effectiveness.[15] In order to control this factor it was necessary to devise such an activating mechanism that the rate of depression of the several releasing levers, and so the speeds of onset of the several pressures, would always be uniform. The relative stimulus values would then be dependent simply on the distances of the points of suspension from the fulcrum.[16] The activating mechanism devised consisted essentially of an eccentric revolving at a constant speed and with which any releasing lever could be independently connected and consequently independently depressed. Since the rate of depression and so the speed of onset depended on the rate of the eccentric, it was the same for each lever. The details of construction are as follows: the apparatus illustrated in Fig. 1 was mounted on a rigid platform about 45 cm. from the floor. The apparatus was screwed to the platform in such a way that its base was horizontal and ran parallel to the edge of a heavy table 85 cm. in height. Both platform and table were screwed to the floor. The ends of the long arms of the releasing levers were nearest the table; they were about 5 cm. from the vertical projection of the table edge.

On the table top was a bank of operating keys, each 55 cm. in length, which were pivoted at their centres on a round steel bar running parallel to the table edge. The ends of these operating keys projected over the table edge and were held down to it by rubber bands. Each key was lined up with a releasing lever. A screw eye in the end of each releasing lever was connected by means of "Glossilla Rope" (embroidery silk) with the end of the corresponding operating key. At each of the latter positions there was means of adjusting the length of "rope."

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[15] We tried depressing the releasing levers by hand and found it impossible to maintain a sufficiently constant rate of depression. A number of pressure apparatus have been described which aim to control the speed of onset with precision. Cf. v. Frey, M. and Pauli, R.: opp. citt. Clark, G. P.: On Certain Characteristics of the Pressure Sensations of the Human Skin. Am. Journ. Physiol., 1898, 1, 356-7. Brückner, A.: Die Raumschwelle bei Simultanreizung., Z. P. P. S. O., 1901, 26, 34. Cook, H. D., and v. Frey, M.: op. cit., 539-541, 541-4. The present apparatus probably admits of more accurate control of this important factor.

[16] "With larger surfaces than those of the test hairs . . . . the physiological effectiveness of the deformation-producing stimulus becomes proportional to its pressure." Clark, G. P., op. cit., 348.

There was sufficient slack in each rope so that the series of loops hung down some 30 cm. below the ends of the releasing levers. A long crankshaft of polished steel, with an offset of 5 cm., passed through the loops. Its axis lay in the same vertical plane as the points of attachment of the ropes in the screw eyes at the ends of the releasing levers. The crank was approximately parallel to the table edge and to imaginary lines passing through the ends of both the releasing levers and the operating keys. At one end of the crank was a driving pulley and at the other end a flywheel. The pulley was belted, through a series of reducers, to a constant speed motor. The crank revolved at the rate of 90 deg. per second or 1 revolution in 4 seconds. The size of the loops was so adjusted that with the crankshaft revolving, manual depression of an operating key would sufficiently raise the loop in the rope, that the crankshaft would engage it on reaching the lower part of its revolution. The result was a tightening of the rope with consequent depression of the corresponding releasing lever. The rubber bands in the suspension of the weights were to reduce the sharpness of onset at the moment of clearance. They did not sensibly stretch but simply became straightened out. The rubber bands around the lead weights made the return contact of the lever and weight smooth and noiseless. In order to keep the silk loops hanging straight downward and so to prevent them from becoming tangled with each other or creeping up and getting twisted around the continuously revolving crankshaft, each was provided with a small sliding weight which was constantly held by gravity at the lowest point of the loop. For the sake of uniformity in onset speed, considerable care was taken in the preliminary adjustments to insure the same angle of depression for each releasing lever at a given position of the crank. The adjustments were verified occasionally throughout the research.

The operation of stimulus lever L′ is in the main similar to that of L. The principal difference is that it produces only one value of stimulus with a given initial weight and a given stimulus weight. Lever L′ has one 10 g. lead weight which is suspended midway between fulcrum and contact area. Its stimulus value is consequently the same as that of weight No.

3 (the middle weight) of lever L. The corresponding releasing lever is directly below L′ and between releasing levers 1 and 2 of L. It is looped to an operating key which is situated between keys 1 and 2 and plays upon their common axis.

Aside from the six loops already mentioned, there is a seventh thread which is loosely tied to the crank near one end. The free end of this thread is attached to the end of a small walking beam pivoted on the axis of the operating keys. The other end of the beam is counterweighted. When the crankshaft revolves, this beam consequently moves up and down. It serves as a signal to the experimenter, indicating to him the phase of the crankshaft and so the proper time of depression of an operating key for presenting a stimulus. It is necessary to depress the operating keys when the crankshaft is in the upper part of its revolution; because otherwise the manual movement of depression might complicate the uniform depression of the releasing lever caused by the uniform revolution of the crank.

The momentary speed of onset, that is, the velocity of a given releasing lever, at the time and place of clearance of the lead weight was mathematically calculated to be approximately 3.7 cm. per sec.[17]

Distinct from the prior problem of determining the suddenness with which the stimulus pressure is added to the initial pressure, there is the problem of obtaining the curve showing the temporal and spatial character of the cutaneous depression during stimulation. Related to this question is the further one of controlling the release of pressure following the positive downward pressure. The latter pressure was the significant stimulus employed in this research; and very early the unmodified negative pressure was found to be confusing. To prevent this confusion, the releasing levers were damped so that they would take up the weights several times more slowly than they released them. The damping was accomplished by oil resistances to brass pistons, the rods of which were pivoted to the releasing levers and the heads of which played in small (13 mm. bore) brass cylinders, C, filled with light oil. Through each piston head were two holes over which a smooth metal washer rested. When a releasing lever was depressed, the piston moved easily down the cylinder because the oil could pass up through the holes against the weight of the washer. When a releasing lever was itself released, however, the head of oil above the piston pressed down on the washer and the lever returned slowly to its original position by the force of a rubber band.

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[17] The writer obtained the result 3.72 cm. per sec. by trigonometrically calculating the amplitude of movement of a given releasing lever, with operating key depressed, while the crank moved through an arc of one degree. The midposition of this one degree arc was at the point held by the crank, when the lead weight barely cleared the lever-arm. The speed of the lever at the time of clearance was approximately determined by taking the mean of the amounts of lever-movement during the first 30′ of arc and the second 30′ of arc. Since the rate of the crank was known, the times of these movements were readily obtained, and the mean of the movements expressible in cm. per second. The fact that the rope loop is not equivalent to a simple connecting rod between crank and releasing lever was taken into account, and also the position of the lead weight with reference to the fulcrum of the lever. The result obtained by this inexact method was verified by Mr. E. G. Fisher, Jr., student of mathematics, who, working independently with the calculus, obtained the result 3.73 cm. per second.

The operation of the entire pressure apparatus was extraordinarily quiet. While with the ear in close proximity to the moving parts, certain sounds could be heard, they were inaudible to the observer when seated in the experimental position.

Photographic records have been made of the curve of the sinking of the contact area into the cutaneous surface and of its gradual rise when the stimulus weight is picked up by the rising releasing lever.[18]

Plates were obtained exhibiting the curves corresponding to each of the five stimulus weights, and under two sets of conditions, first, when the contact object rested on the observer's upturned right middle-finger berry, and second, when the contact object rested on the apex of a square red rubber pyramid one cm. in height and with a base one-half cm. square. The pyramid was mounted on blotting paper. Figures 2 and 3 are reproductions of plates obtained under these respective sets of conditions.

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[18] The photographic method of making the records was essentially as follows: A V-shaped frame was attached to the end of stimulus lever L, and served to support a single taut silk fibril about 2 cm. in length, situated above the area of contact. By means of an arc-light, the Dodge microscope recorder, and a rectifying total reflection prism, minimal movements of the fibril corresponding to minimal vertical movements of the contact area could be photographed on the falling plate of a Dodge camera, situated one meter distant. The optical magnification was approximately 115 diameters. Over 140 plates were exposed with this set-up.

The procedure was to first start the crankshaft revolving and then get the subject's finger, or the artificial finger, correctly adjusted beneath the contact object. The arc-light was then adjusted, the plate released, and a manipulating key depressed so that a stimulus was presented while the plate was falling through the projected field containing the shadow of the fibre. Since the fibre-support was rigidly attached to the contact-support, the vertical movement of the fibre was of the same magnitude as the vertical movement of the contact area into the finger. Consequently our depth measurements of curves of the fibre-shadow, when divided by the optical magnification, give magnitudes of cutaneous depression. Again, since the fibre-support is one with the contact-support, our time measurements from the fibre-shadow curve are those for the identical curve of the contact area.

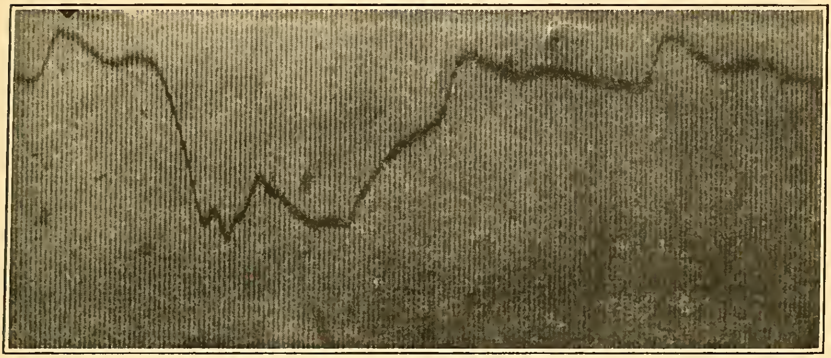

Fig. 2

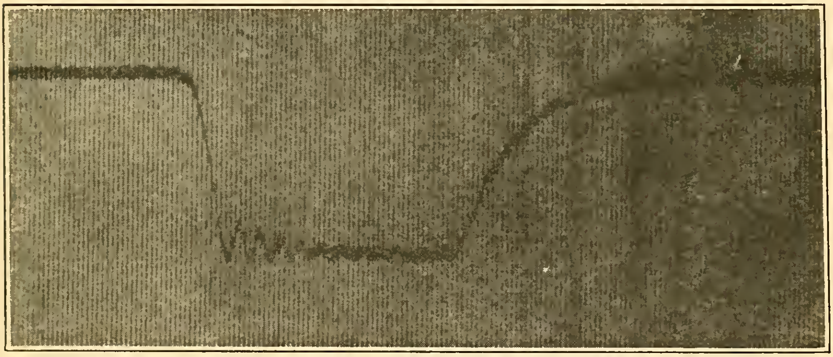

Fig. 3

Figs. 2 and 3 are records exhibiting the physical aspect of the pressure stimulus. Fig. 2, the upper, is the curve of depression during stimulus-pressure on an observer's finger-berry; complicating pulse thrusts are shown. Fig. 3, the lower, is the curve when the pressure is on an artificial finger-berry of red rubber. The time ordinates are 1/60″ apart.

Each shows the curve corresponding to stimulus weight No. 5. The times occupied by the sinking, resting, and rising phases, respectively, are approximately the same for each stimulus weight, as indicated by the mean variations of Table I. In other words the only significant difference in the curves

TABLE I

The temporal relations of the physical pressure

Phase	Sinking	Resting	Rising	Total Time	No. of Plates
Average	.17″	.79″	1.25″	2.21″	10
M. V. (% of Av.)	0	16	16		

corresponding to the different stimulus values is the difference in height due to the differences in the magnitude of cutaneous depression. Attention is called to the fact that, for the plates measured, and within the limit of accuracy which is 1/60″, there is *no* variation in the time of the sinking phase, which is the important phase in stimulation. The various magnitudes of depression for the various stimulus values are presented in Table II, which gives results for the human finger with 10 and 20 g. initial weights and for the red rubber pyramid with 20 g. initial weight.

TABLE II

The magnitudes of cutaneous depression

	Depression mms.					Initial W't., gs.	Number of Plates
No. of Stimulus Weight	1	2	3	4	5		
Subject N.	.06	.13	.15	.22	.26	10	10
Subject N.	.05	.09	.13	.17	.20	20	20
Red Rubber Pyramid	.04	.08	.13	.16	.20	20	10

The curves of Fig. 4 exhibit graphically the data of Table II. The ordinates are the various stimulus designations and the abscissae are magnitudes of depression in mms.

Plate measurements were rendered somewhat difficult because of the prominence of the pulse thrust, which is clearly represented in Fig. 2 and obviously complicates the pressure curve. It was for the purpose of getting more accurate measurements, by elimination of the pulse thrust, that photographs such as Fig. 3 were made which show the curve when an artificial finger of red rubber was 'stimulated.' Fig. 4 shows that the magnitudes of depression when the red rubber was used are comparable to those for the human finger. The figures in Table I are the results of red rubber depressions.

The measurements show that the magnitude of vertical movement referable to the systolic pulse thrust (when the

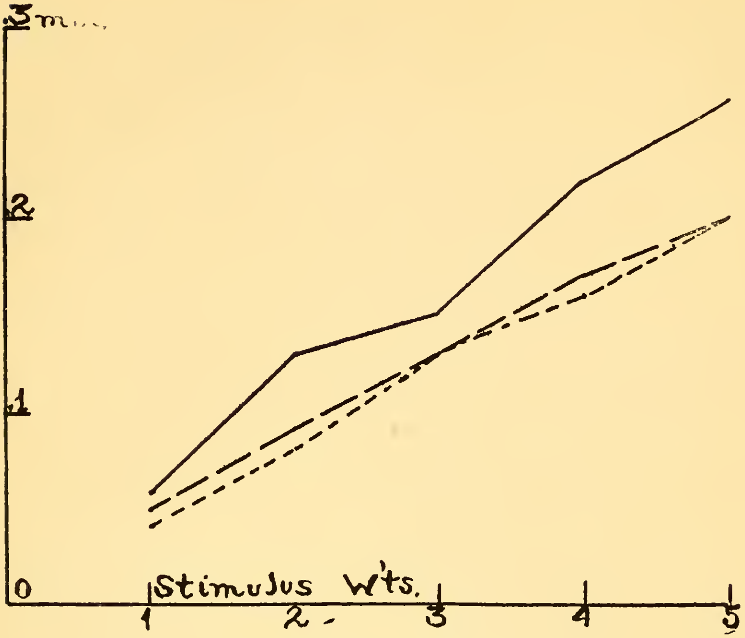

Fig. 4

Fig. 4 gives curves, the forms of which indicate the relations between the various magnitudes of cutaneous depression corresponding to the various stimulus designations. The solid line is for subject N. (See Table II.) with 10 g. initial weight; the coarse broken line is for subject N. with 20 g. initial weight; and the fine-broken line is for the red rubber "finger" with 20 g. initial weight.

subject is quiet and unexcited) is about 0.8 of that due to the smallest or No. 1 stimulus weight. The first vertical column of figures of Table III shows this.

TABLE III

Ratio of systolic pulse thrust to stimulus thrust in per cent of the latter

	Pulse Ratio					Initial W't., gs.	Number of Plates
No. of Stimulus Weight	1	2	3	4	5		
Subject N.	76	37	30	20	15	10	10
Subject N.	83	45	28	25	20	20	20

This estimate taken with the fact that the No. 1 stimulus was found to be but slightly superthreshold led us to believe that the pulse thrust might be a limiting sensibility factor, and so render these incidental results of theoretical importance.[19]

Introspective reports throughout the pressure experiments indicate that the stimulus usually produced a smooth regular pressure. 'Thrusts nice and clean-cut.' It increases rapidly to a maximum and then fades out. The last phase, that is, the slow release of the pressure was less intense and did not seem to confuse the judgments of the more intense earlier phase. The observers regularly became adapted to the constant pressure.[20] 'The constant stimulus dies out almost completely.' 'After first stimulus the 10 g. weight (constant initial pressure) was no longer felt.' When presented successively the five pressures used were clearly discriminable.

Occasional qualitative differences were observed however: both a 'constant pressure tickle' and a stimulus or momentary tickle were reported. There was reported awareness of the finger pulse in parts of eight part-series. 'Pulse more noticeable in case of the lighter stimulus pressures.' 'Increased blood pressure in the hand.' Observer D reported in one series that the stimulus 'pressure spread noticeably to other fingers of the hand. This was more noticeable for the heavier pressures.' The fingers, arm, or shoulder were sometimes (11) reported asleep or cramped; but usually the observer seemed to be comfortable. Muscle tremors were rarely (3 times) reported. 'Probably some faint stimuli got lost in muscle tremors.' 'Uncertainty as to throb or faint stimulus.' Either the fingers moved slightly or there was a tendency to movement (11 times).

With regard to quantitative differences, the hand was reported cold (5 times) and also was markedly *less sensitive*

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[19] It must be noted in connection with this speculation that in some of the experiments (Table XV) depressed respiration was shown to be accompanied by a significant lowering of the stimulus limen. In this case the stimulus thrust must have been less than the normal pulse thrust. That is to say, a normally subthreshold thrust becomes superthreshold when, as commonly occurs in depressed respiration, the systolic pulse thrust is reduced in amplitude. The relation between pressure limen and pulse seems to deserve detailed investigation with modern techniques.

The pulse-thrust has been reported in some cutaneous, threshold work, but with surprising infrequency in view of its seeming importance. Cf., Dodge and Benedict; Psychological Effects of Alcohol; Carnegie Institution of Washington, 1915, 137; and reference there given. Also present investigation, p. 20.

[20] Clark noted a rapid fatiguing out of continued areal pressure. Op. cit., 350-2.

(2 times). In three other recorded cases there was a noticeable difference in sensibility with no ascribable cause. In two of the cases the observer was less sensitive than usual throughout the experimental sessions; while in the third there 'seemed to be a sudden increase of pressure which remained' for a period during which 5 pairs of stimuli were presented. This introspective account of the pressure experience makes no pretense of being exhaustive; our primary interest lies in the effect of attention.

Procedures and Results

Summary.

(a) Comparison of successive areal pressures on the same cutaneous surface, and without experimental control of attention, results in a marked tendency to underestimate the second pressure. No adequate method was discovered for comparing successive pressures presented under different degrees of attention. (pp. 21-29).

(b) Comparison of simultaneous areal pressures on the middle-finger berries of the left and right hands, when attention is directed to a given hand, results in tendency to overestimate the pressure corresponding to the hand attended to. The overestimation-tendency does not appear when the observer attempts to visualize the finger and the areal contact resting upon it. (pp. 29-38).

(c) Judgments of an approximately liminal areal pressure after three prestimulus situations favoring respectively different degrees of attention at the time of stimulation indicate that the number of superthreshold stimuli tends to vary directly with the presumptive degree of attention. Depressed respiration seems to lower the threshold. (pp. 38-45).

GROUP I.

The original purpose in these experiments was on the one hand to amass baseline data to be compared with subsequent distraction results, and on the other hand to discover some suitable form of distraction for modifying attention to the pressure. In these series the area of stimulation was the upturned middle-finger berry of the observer's left hand. The observer sat with his back to the apparatus and with his left arm partly extended behind him. The back of the fingers, hand, and wrist were supported and wooden guides were provided for the first and third fingers. This arrangement provided a relaxed and generally comfortable position for the hand and finger. As noted above, certain infrequent minimal movements of the finger and rarely a slight tremor were noted by the observer. We aimed to throw out all judgments made under unusual or disturbing conditions. The last statement applies to all the experiments. In each series of Group I the successive pressures compared were presented at the same cutaneous surface.

Series 1 and 2, Control Experiments. We expected that, of two successive stimuli without a preliminary signal, the second stimulus would have the advantage of expectant attention. In case attention modified intensity this would give a constant bias to the results. Whether or not such a bias existed was the problem of this control series. We aimed to make a baseline experiment for comparison with later experiments under different conditions of attention. To this end, no instruction concerning direction of attention was given, and no special attempt was made to produce attention-differences for the first and second pressures of comparison pairs. No discrete ready signals were given. But since the interval between compared pressures was uniform while the interval between pairs varied, the observer doubtless knew more nearly the time of the second than of the first pressure.

The instructions were as follows: "(1) You will be presented with paired pressures. The interval between the members of each pair will be the same. (2) After the second pressure judge and report whether it is equal to, heavier, or lighter than the first pressure. (3) If there is but one pressure instead of a pair, report 'one.'" (4) The observers were instructed to abstract from the pressures of release and judge the positive pressures only.

The interval between the onsets of the pressures to be compared was 4″. The interval between comparison pairs was variously 4, 8, or 12″. Series 1 and 2 were temporally mixed. The difference in the conditions of the two was that in Series 1 a 10 g., and in Series 2 a 20 g. initial weight was employed. Since the initial depression is less, the stimulus increments are greater in Series 1 than in Series 2. Table II and Fig. 4 show that the depressions are greater when the 10 g. weight is used. The five different magnitudes of pressure given by stimulus weights 1 to 5 of stimulus lever L were used. With five magnitudes of pressure it is possible to arrange 25 different pressure pairs, i. e., the permuted combinations of 2, plus 5 respective pairs in which the first and second pressures are equal.

Twenty-five such pressure pairs were presented during a single setting of the observer's finger, and in chance order. Four of these sub-series of 25, or 100 pressure pairs, were employed during a single sitting of the observer. This was the maximum experimentation in the case of each observer for a single day. The time required was about 35 minutes. A total of 500 pressure pairs were presented to each one of the 4 observers.

The data were classified according to the 'true' and 'false' judgments. All judgments were placed in the 'true' category which were in correspondence with the relative magnitudes of the physical pressures. If, e. g., a pressure pair was composed of two No. 3 stimuli and an equality judgment was given, it would be correct. If the stimuli were Nos. 4 and 5 respectively, the correct or true judgment would be 'heavier.' Similarly, the false judgments were those which were not in correspondence with the physical pressure. The false judgments, i. e., those judgments in which we are especially interested, subdivide into categories of under and overestimation. If, e. g., the stimuli of a pair were two Nos. 3 and the judgment was 'lighter,' it would be an underestimation, and if 'heavier,' an overestimation.

Again, if the stimuli were Nos. 4 and 5 the judgment 'equal' would be underestimation; and if the stimuli were 5 and 4 the judgment 'equal' would be overestimation. A number of false judgments of higher orders were made; if, e. g., the stimuli were Nos. 5 and 2, an equality judgment would be an overestimation of the third order. In the following tables all judgments were treated as of a single order.

Tables IV-VII are of similar arrangement. Each contains the results for a single observer. The first vertical column of each table contains the numbers of experimental sessions. In the next two columns are the numbers of true judgments, respectively, when the 10 g. and when the 20 g. initial weight was used; in other words, with the larger and the smaller stimulus increments. In the next column the corresponding totals are given. The overestimations and underestimations are each arranged in the same way as the true judgments, and are given in adjacent columns to the right. In the last two columns at the right of the table are respectively the numbers of judgments made, and of stimuli presented. There are somewhat more of the latter because in a few instances the observer was apparently unconscious of either one or both stimuli, making judgment impossible. These instances occurred at the lower pressures and are ascribable to disturbances such as noted above in the account of the introspective nature of the stimulus, and to brief attention lapses. Table VIII summarizes the results of Series 1 and 2 in percentages. The left hand vertical column gives the observers. The next three columns give respectively, the true, over-, and under-estimations. These total 100 per cent in each horizontal row as indicated in column five. Columns six and seven show the percentage-relationships between the over- and under- estimations when considered apart from the true judgments. That these total 100 per cent in each horizontal row is indicated in the last column.

Judgments of the comparative intensity of successive pressures in terms of the second pressure

TABLE IV
Observer D

	True			Overestimat.			Underestimat.				
Initial Weight in gs.	10	20	Total	10	20	Total	10	20	Total	Sum	No. of Stimuli
Experimental Session No. 1	38	38	76	4	5	9	6	4	10	95	100
" " 2	36	40	76		2	2	13	2	15	93	100
" " 3	29	39	68	5	3	8	11	6	17	93	100
" " 4	39	35	74	3	5	8	7	8	15	97	100
" " 5	37	32	69	1	3	4	10	8	18	91	100
Total	179	184	363	13	18	31	47	28	75	469	500
Average	35.8	36.8	*72.6*	2.6	3.6	*6.2*	9.4	5.6	*15*	93.8	100

TABLE V
Observer F

	True			Overestimat.			Underestimat.				
Initial Weight in gs.	10	20	Total	10	20	Total	10	20	Total	Sum	No. of Stimuli
Experimental Session No. 1	30	32	62	3	3	6	13	9	22	90	100
" " 2	33	28	61	3	4	7	6	12	18	86	100
" " 3	37	36	73	2	4	6	9	6	15	94	100
" " 4	35	34	69		2	2	7	6	13	84	100
" " 5	38	32	70	3	2	5	7	14	21	96	100
Total	173	162	335	11	15	26	42	47	89	450	500
Average	34.6	32.4	*65.2*	2.2	3.	*5.2*	8.4	9.4	*18*	90	100

Judgments of the comparative intensity of successive pressures, in terms of the second pressure

TABLE VI

Observer N

	True			Overestimat.			Underestimat.				
Initial Weight in gs.	10	20	Total	10	20	Total	10	20	Total	Sum	No. of Stimuli
Experimental Session No. 1	36	39	75	5	6	11	9	4	13	99	100
" " 2	36	37	73	6	6	12	6	5	11	96	100
" " 3	34	36	70	6	3	9	8	8	16	95	100
" " 4	37	35	72	4	4	8	6	10	16	96	100
" " 5	38	39	77	4		4	7	9	16	97	100
Total	181	186	367	25	19	44	36	36	72	483	500
Average	36	37	*73*	5	3.8	*8.8*	7.2	7.2	*14*	97	100

TABLE VII

Observer W

			True	Overestimat.			Underestimat.				
Initial Weight in gs.	10	20	Total	10	20	Total	10	20	Total	Sum	No. of Stimuli
Experimental Session No. 1	36	42	78	6	4	10	7	3	10	98	100
" " 2	34	41	75	4	2	6	11	5	16	97	100
" " 3	35	39	74	5	5	10	9	4	13	97	100
" " 4	32	33	65	6	7	13	9	8	17	95	100
" " 5	34	36	70	7	6	13	8	6	14	97	100
Total	171	191	362	28	24	52	44	26	70	484	500
Average	34	38	*72*	5.6	4.8	*10*	8.8	5.2	*14*	97	100

TABLE VIII

Percentage summary of all judgments of comparative intensity of successive pressures

	Percent of All Judgments				Percent of False Judgments		
	True	Overest.	Underest.		Overest.	Underest.	
Observer D	77	7	16	100	29	71	100
" F	74	6	20	100	23	77	100
" N	76	9	15	100	38	62	100
" W	75	11	14	100	43	57	100
Average	76	8	16	100	33	67	100

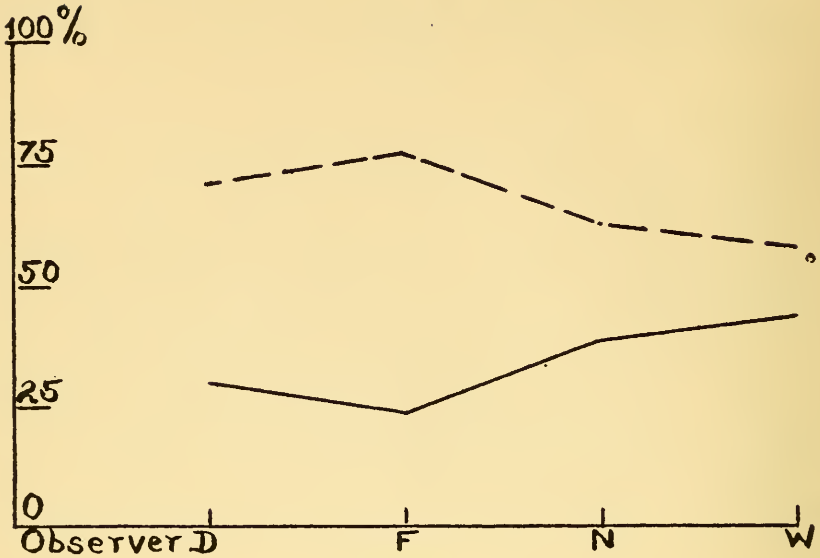

Fig. 5

Fig. 5 exhibits the data of the right hand part of Table VIII, showing the uniform tendency to underestimate the second of two successive pressures. The solid line is for overestimations and the broken line for underestimations.

Results of Series 1 and 2.

1. Comparison of the 'total' columns for the overestimations and the underestimations in each table, shows that there is a uniform tendency for each observer to underestimate the second stimulus. The same fact is plainly indicated in the last two columns but one, of Table VIII. This latter result is graphically exhibited in Fig. 5.

2. Comparison of the first two columns of underestimations in each table, shows a somewhat greater tendency to underestimation of the second stimulus when using the larger than when using the smaller stimulus increments. (As explained on p. 22, the *greater* depression or increment is obtained when the 10 g. initial weight is used and the lesser when the 20 g. initial weight is used.) For observers D. and W. the tendency is marked, for N. the numbers of cases are equal, and for F. there are slightly less underestimations with the larger than with the smaller stimulus increments.

3. Comparison of the first two columns, i. e., the true judgments, in each table, shows that for each observer except F.

there are more false (less true) judgments when using the larger than when using the smaller stimulus increments.

Series 3 and 4; Distraction Experiments. The aim in these experiments was to discover some suitable form of distraction for abstracting attention from the pressure. The plan in general was to use the distractor during the presentation of one of the pressures of the pair, and for the observer to 'compare' the intensities of the pressures. The procedure was similar to that of Series 1 and 2 except for the distraction factor, the smaller number of cases, the fact that only the 10 g. initial weight or larger stimulus increment was used, and that only observers D. and N. served.

The forms of distraction tried are briefly described below. In Series 3, by means of an horizontal kymograph with threaded shaft, a screen with electrically controlled exposure slot, and a silent motor, typewritten capital letters were successively presented to the observer as a means of distraction from the first pressure. The characters formed 5-letter substantives and they passed the exposure slot, backwards, in a vertical column at the approximate rate of one letter per second. The task of the observer was to read the letters, synthesize, and orally report the words. The visual signal for the end of distraction and for preparation to receive the second pressure (expectant attention) was the silent closure of the exposure slot.

This distraction proved introspectively unsatisfactory. Both observers frequently reported a 'division of attention' between the distractor and the simultaneous pressure.[21] There was a 'surprising apparent parallelism of attention.' 'Both pressure and distractor were clear at the same time.' There was also reported 'division of attention with lapses on both sides'; but in general 'there was conspicuous absence of shifting of attention back and forth' between distractor and pressure which was 'very striking.' They also reported difficulty in retaining the first pressure for comparison with the second; and difficulty in recalling whether or not a first pressure had been experienced in cases where only the second pressure was certain. The memory factor involved in the comparison of successive pressures[22] was thus a real difficulty. It was felt that most of the 'judgments were rough; could not be accurate.' The numerical results (275 cases) calculated as in Series 1 and 2, show no clear tendency to over- or under-estimate the second pressure.

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[21] Apparent division rather than oscillation of attention has also, e.g., been noted by Külpe, O.: Outlines of Psychology: 1895, (Ger. 1893), 160. Drew, F.: Attention—Experimental and Critical: Am. Jour. Psychol., 1895, 7, 566. Brückner, A.: op. cit., 54, 60. Boring, E. G.: Cutaneous Sensation after Nerve-Division: Quart. Jour. Exp'l. Physiol., 1916, 10, No. 1, 93. J. P. Hylan concluded that neither distribution nor division of attention really occurs although frequently seeming to do so. According to him the effect may be due to rapid oscillation of attention among the various objects; or it may be due to the fact that a number of previously disparate objects have become unified by repeatedly experiencing them together, and are hence attended to as a unity; or in tachistoscopic experiments on the "range of attention" it may be due to the fact that the observer does not realize that he is counting the objects from the memory after-image. Cf., The Distribution of Attention: Psychol. Rev., 1903, 10, 373-403, 498-533.

In Series 4 the distraction of Series 3 was complicated by an additional task, i. e., attempt to maintain a vertically oscillating rectangle of light upon the exposure slot, so that the exposed letters would be legibly illuminated. To do this the observer had to move a vertical wire several inches up and down, irregularly, with the right hand. The fore-arm lay flat on the chair-arm and the movement was an easy wrist movement.

But under these circumstances also the introspective difficulties of Series 3 appeared. There was 'still the division of attention, but the hand was not in consciousness so much as before.' 'Real shifts of attention' from distractor to pressure were reported. Yet it was 'difficult to affirm attention shift hypothesis.' Still 'the pressure breaks through and appears alongside of the letter-attention.' There is 'no difficulty in keeping the slit illuminated except during reading.' 'Most complete attention to the distraction when I get behind (in the reading) and try to catch up.' Forgetting the first pressure, that is, whether or not it existed at all, or its intensity, was more frequently reported than in Series 3. Again the numerical results (150 cases) show no clear tendency. The introspection indicates somewhat greater detraction of attention than in Series 3. This harmonizes with the apparent superiority of the double task over the single task method.[23]

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[22] This difficulty is not new. Swift, E. J.: Disturbance of the Attention During Simple Mental Processes: Am. Jour. Psychol., 1892, 5, 18. Daniels, A. H.: The Memory After-Image and Attention: Am. Jour. Psychol., 1893, 6, 558-564. Moyer, F. E.: A Study of Certain Methods of Distracting the Attention. Am. Jour. Psychol., 1896-7, 8, 412. Hamlin, A. J., op. cit., 49-50.

[23] Cf., Dallenbach, K. M.: The Measurement of Attention in the Field of Cutaneous Sensation: Am. Jour. Psychol., 1916, 27, 458-460; and reference there given.

Several minor complications were tried, using the setups of Series 3 and Series 4. They were unsuccessful. Largely because of the complicating memory factor involved in the pressure-comparisons of these series, it was determined to employ a new method.

GROUP II.

These experiments are a further attempt to select conditions adequate to the investigation of the main problem. The areas of simultaneous stimulation were the upturned left and right middle-finger berries. The observer sat with closed eyes facing the apparatus, his arms supported and partly extended. The palms of the hands pointed inwards, and the backs of the relaxed fingers rested on the stages. The areas of stimulation were approximately 40 cm. apart and placed symmetrically with reference to the median plane.[24]

Series 1: The purpose of this series was to demonstrate the effect, if any, of attention directed, e. g., to the left pressure, upon judgment of the relative intensities of the left and right pressures; as compared with the effect when attention was directed to the other (right) pressure.

A difficult problem, as hitherto, was to control attention. One of the most satisfactory methods found to produce attentional bias to the stimulated hand (the left or the right as the case may be) consists in the task of continually trying to approach the first or third finger and thumb as near together as possible without contact. Observer N. tended also unintentionally and schematically to visualize the physical contact and the finger. F. and W. probably visualized more completely. The following introspective statements partially indicate the degree of adequacy of our attentional detractor. (Observer D.) 'Rather conspicuous how the left (pressure) completely disappeared. Almost seemed like retinal rivalry.' 'Fact of comparison divides attention.' 'Lost attention and had to wait to regain it.' While 'no stimulation is given the only way I can keep attention (to the hand) is by trying to feel the position of the fingers.' 'Left almost disappeared.' There were 'gross differences in the light pressures.' They 'seemed to differ as much as the stimuli.' (F.) 'Maintained attention by visualizing end-pieces of apparatus as well as by approaching the fingers.' 'Attention seemed very good,' (i. e., maintained to the given hand). 'Attention well directed.' 'In spite of all endeavor, it was impossible to keep attention from wandering from the finger in the lapse of time between two successive stimuli.' (N.) 'Other side broke through.' 'Occasional shift of attention to the other side.' 'Attention well directed.' 'Attention distracted.' (W.) 'Attention seemed well abstracted from the other hand.' 'Get steady fixation of attention to the side right through.' In at least one case he lost the pressure he was supposed to attend to apparently because of attention to the *finger* stimulated. He did not expect the stimulus, attention being confined by the problem of approaching the fingers. In most cases he also voluntarily visualized the stimulated position. This gave 'subjectively excellent attention.' 'Attention wandered in two or three cases.' The head was often turned toward the side of attention.

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[24] Introspection indicates that asymmetry tends to be confusing to at least one observer by making him believe that it is invalidating his judgments. Cf. in this connection Drew, F.: loc. cit.

The instructions were as follows: "(1) At regular intervals you will be presented with simultaneous pressures. (2) Close your eyes. (3) Try to keep your attention constantly upon the left (right) hand. Maintain attention by continually trying to approach the first or third finger and thumb as near together as possible without contact. (4) Judge the pressures and report whether the one attended to is equal to, heavier, or lighter than the other."

During these series the knives of the stimulus-lever fulcrums were set out of the nicks so as to allow slight sidewise movement, thereby reducing occasional complicated stimuli due to small chance finger-movements. For each comparison the right hand finger was stimulated with some one of the series of five pressures. The order of presentation of the latter was kept well varied by using five different chance orders, each order containing 25 units. For each comparison the *left* hand finger was always stimulated with the No. 3 stimulus. The stimulus value for the left finger was therefore the same as the middle value (No. 3) for the right finger. At every setting of the fingers the No. 3 stimuli were subjectively equated. In order to judge as to equality the observer would fluctuate from one pressure to the other, then give special attention to neither, and so on, until the judgment was of approximate equality. The equation was usually checked after 25 judgments had been given.

Fifty judgments of the intensities of pressure were made with each single setting of the fingers; 25 of these judgments were made under an instruction to left attentional bias, and 25 under an instruction to right attentional bias. One group of 25 followed the other in time. The total time required was approximately 8 minutes. After 50 comparisons the hands and arms were always removed from the apparatus and rested. No more than 100 comparisons were made with a single observer on a single day. Each of the four observers made a total of approximately 500 comparisons.

The data were treated as in Group I (p. 23), the categories of true and false judgment, over- and under-estimation, being used. In a given group of 50 judgments, the true cases with attention to the left and the true cases with attention to the right, were summed. The over- and the under-estimations were similarly treated, respectively. All judgments are tabulated as single order judgments.

Tables IX-XII are of similar arrangement. Each contains the results for a single observer. The first vertical column of each table contains the numbers of experimental sessions. In the second, third, and fourth columns are given, respectively, the numbers of true judgments, over-estimations and under-estimations. In the last two columns at the right of the table are, respectively, the numbers of judgments made, and of stimulus-pairs presented. There are somewhat more of the latter because in a few instances the observer was apparently unconscious of both stimuli, making judgment impossible. When one pressure only was experienced it was considered for statistical purposes as heavier than the unnoticed pressure. Table XIII summarizes the results of Series I in percentages. The arrangement is precisely the same as in Table VIII. The left hand vertical column gives the observers. The next three columns give respectively the true, over- and under-estimations. These total 100 per cent in each horizontal row as indicated in column five. Columns six and seven show the percentage-relationships between the over- and under-estimations when considered apart from the true judgments. That these total 100 per cent in each horizontal row is indicated in the last column.

Results of Series 1.

1. Comparison of the columns of overestimation and underestimation in each table shows that in general there is a ten-

Effect of attentional bias to one of two simultaneous pressures on judgments of their comparative intensity, with judgment in terms of the pressure attended to

TABLE IX

Observer D

	True	Overest.	Underest.	Total	No. of Stimuli
Experimental Session No. 1	33	10	5	48	50
" " 2	32	16	2	50	50
" " 3	33	14	3	50	50
" " 4	30	16	2	48	50
" " 5	32	15	3	50	50
" " 6	34	14	2	50	50
" " 7	29	18	3	50	50
" " 8	30	18	2	50	50
" " 9	34	13	3	50	50
" " 10	33	15	2	50	50
Total	*320*	*149*	*27*	496	500

TABLE X

Observer F

	True	Overest.	Underest.	Total	No. of Stimuli
Experimental Session No. 1	26	12	11	49	50
" " 2	30	15	4	49	50
" " 3	26	18	6	50	50
" " 4	32	11	7	50	50
" " 5	24	20	6	50	50
" " 6	31	17	2	50	50
" " 7	28	16	6	50	50
" " 8	31	16	3	50	50
" " 9	27	17	6	50	50
" " 10	27	17	5	49	50
Total	*282*	*159*	*56*	497	500

TABLE XI

Observer N

	True	Overest.	Underest.	Total	No. of Stimuli
Experimental Session No. 1	36	10	4	50	50
" " 2	33	6	11	50	50
" " 3	25	16	9	50	50
" " 4	31	13	6	50	50
" " 5	35	10	5	50	50
" " 6	38	9	3	50	50
" " 7	37	8	5	50	50
" " 8	36	10	4	50	50
" " 9	34	12	4	50	50
" " 10	33	10	7	50	50
Total	*338*	*104*	*58*	500	500

TABLE XII

Observer W

	True	Overest.	Underest.	Total	No. of Stimuli
Experimental Session No. 1	36	3	11	50	50
" " 2	29	7	14	50	50
" " 3	32	10	8	50	50
" " 4	35	5	10	50	50
" " 5	38	4	7	49	50
" " 6	33	10	7	50	50
" " 7	24	13	13	50	50
" " 8	35	7	8	50	50
" " 9	30	11	9	50	50
" " 10	31	8	11	50	50
Total	*323*	*78*	*98*	499	500

TABLE XIII

Percentage summary of judgments of simultaneous pressures under attentional bias

	Percent of All Judgments				Percent of False Judgments		
	True	Overest.	Underest.		Overest.	Underest.	
Observer D	65	30	5	100	85	15	100
" F	57	32	11	100	74	26	100
" N	68	21	11	100	64	36	100
" W	65	16	19	100	44	56	100
Average	64	25	11	100	67	33	100

dency to overestimate the pressure corresponding to the hand attended to.[25] For observers D., F., and N. this tendency is marked and uniform. For W. there are somewhat less overestimations than underestimations, but the distribution of judgments is irregular. Table XIII and the corresponding Fig. 6 plainly exhibit the tendency to overestimate.[26]

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[25] Drew found, in a somewhat similar situation on the contrary, that "when attention was given to the hand, the shock-stimulus was usually weakened, and at times to so great an extent as to leave room for doubt whether it had really been sensed or only expected." Op. cit., 548-9.

[26] While Fernberger, in difference-limen experiments with lifted weights, has shown that the change in attitude produced by changing the usual instructions, so as to give uniform emphasis to the respective judgment-categories, is accompanied by an increase of over 60% in the average interval of uncertainty; it is interesting in connection with our results that the increase accompanying *such* attitudinal change is biased in neither one direction nor the other. Cf. Fernberger, S. W.: The Effect of the Attitude of the Subject upon the Measure of Sensitivity. Am. Jour. Psychol., 1914, 25, 538-543.

In this group of our experiments, were it not for the fact that two of our observers worked without knowledge of the problem, Fernberger's results might suggest that our overestimation-tendency was as much an attitudinal affair as the increase in his measure of sensitivity.

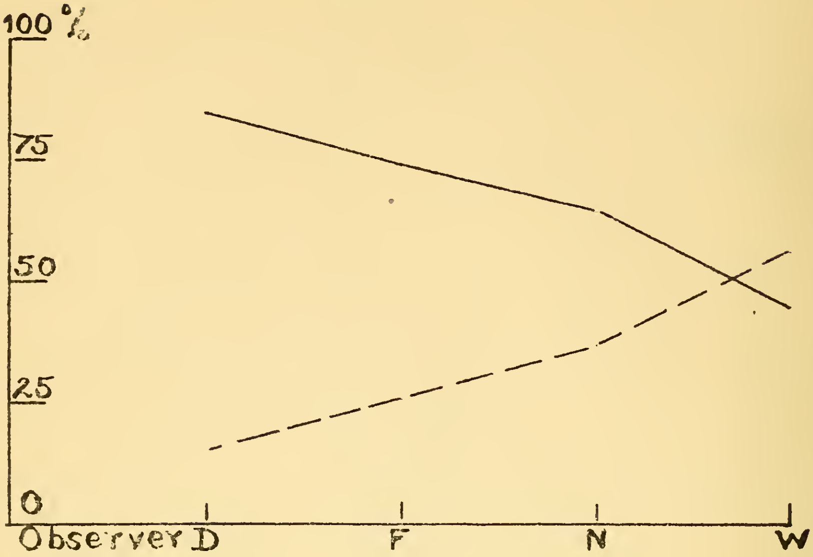

Fig. 6

Fig. 6 exhibits the data of the right hand part of Table XIII, showing the tendency to overestimate the one of two simultaneous pressures presented under attentional bias. The solid line is for overestimations and the broken line for underestimations.

2. Table XIII shows that the distribution of the true and false cases is roughly the same for each observer; the per cent true cases varies from 57 for F. to 68 for N.

3. Table XIII shows that the distribution of the overestimations and underestimations differs widely among the observers; the percent overestimated (3d column from the right) varies from 44 for W. to 85 for D.

Series 2: These experiments were made in order to show the effect produced on the intensity-judgments when various different aids were employed in directing attention. Our purpose was to find some more efficient means of detraction than that used in Series 1.

Four methods were tried, the experiments in each constituting a sub-series. We aimed to aid the direction of attention by: (1) continually trying to approach the thumb and finger as near together as possible without contact as in Series 1., (2) light momentary contact of thumb and finger at the time of the 2″ preparatory signal, (3) trying to retain the pressure image of the prior pressure, (4) trying to visualize the finger and the areal contact resting upon it. Introspectively the observiers, i. e., D. and N., found neither of the first three methods outstandingly the most adequate. D. found it relatively effective to attend to pressures from the hand as a whole, as well as to the pressure image of the preceding stimulus (method 3). N. seemed to have the best success by bringing the thumb into slight momentary contact with the first finger at the time of the 2″ signal (method 2) and then straining to hold the minimal pressure image. D. and N. found the visualization method highly unsatisfactory. Only very rarely was a clear visual image obtained, and even then it was usually impossible to hold it during the time of stimulation.[27] (D.) 'Very great difficulty in keeping image.' 'Very bad attention.' 'Very unsteady imagery, very unsatisfactory: the instability is distracting.' (N.) 'Hard to keep visual image: no time to get it firmly in mind before the stimulus occurs.' 'Visual image sometimes failed—seemed disconnected with the process. 'Less sure of accuracy of judgments in visualization.' In each of the four sub-series for each observer there was occasionally the difficulty of keeping attention away from the one hand apparently just *because* the observer was trying to attend to the other hand.

It is to be noted that each of the methods tends to a metaphorically spatial direction of attention rather than an exclusive concentration on the pressure intensity itself. Attention is directed, as it were, to the left or right side and to the corresponding hand and finger. It is believed that we have often succeeeded in obtaining an expectant attention by which the observer is highly prepared to receive the stimulus.[28]

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[27] In connection with the superiority of the first three methods over the fourth, it is interesting to note that some thirty years ago it was reported that attention directed to images from different senses had markedly different effects on the images. Attention to a visual memory image which has *appeared effortlessly* and is even highly clear, is accompanied by confusion and disappearance of the image. The assumption here of a high degree of clearness simultaneous with a low degree of attention is theoretically interesting. Attention to a motor or tactual image, on the other hand, gives it greater emphasis. Cf., Lalande, A.: Sur un Effet Particulier de l'Attention Appliquée aux Images: Rev. Philos., 1893, 35, 285-7; and Paulhan, F.: L'Attention et les Images: Rev. Philos., 1893, 35, 502-7. Pyle observed that the state of expectation, known by others as 'expectant attention' was generally unfavorable to visual imagery because of preponderating kinaesthesis. Cf., Pyle, W. H.: An Experimental Study of Expectation: Am. Jour. Psychol., 1909, 20, 553, 556, 559, 561, 568.

Weber's method of heightening Tastaufmerksamkeit by attending to minimal pressure thrusts is one to which our second and third methods are in general similar. Cf., Weber, E.: Ein automatischer Regulationsmechanismus der Empfindungsstärke. II, Der Einfluss lokalisierte Aufmerksamkeit auf die Blutfülle der tastenden Hautpartie., Archiv für Anatomie und Physiologie; Physiolog. Abt., 1910, 465-6. Also Drew, op. cit., 545: "Attention to a hand often degenerated to a stupid stare until the plan was formed to slightly raise the hand, as if 'hefting' it, at the same time slightly innervating the fingers. By this means attention was known to be *in* and not merely toward the hand, and 'inner' and 'outer' attention were made to coincide."

The instructions were the same as for Series 1 (p. 30) except for the proper changes in regard to the method of maintaining attention and notice of the 2″ 'ready' signal.

A physical difference between Series 1 and Series 2 is that the latter employed simultaneous stimuli whose values were each No. 3. Vexierversuche of values 2 and 4 were occasionally (4 in each 24 pairs) used on the right finger. The No. 3 stimuli were subjectively equated for each setting of the fingers, as in Series 1. The equation was checked at the ends of the periods. No more than 40 judgments, exclusive of Vexierversuche, were made during each setting. After 10 experimental judgments under a given (left or right) attentional bias, a change was made to the other side, 10 experimental judgments being obtained under the opposite attentional bias, and so on. Changing the direction of attention, in this way, so frequently during a given setting of the contacts, makes it quite impossible for bias in the number of pressure judgments to be due to physical readjustment or shifting of the fingers.

Only a small number of judgments were made, i. e., 119 for method 1 of detraction, 120 for method 2, 88 for method 3, and 160 for method 4. The indications of the results are hence only to be accepted with considerable reservation. The data are treated as heretofore.

Table XIV contains the numerical results for Series 2. The first vertical column gives the observers, and numerals which designate the methods used. The next two columns, which are under 'True,' give the correct judgments in the terms of numbers of cases and percentages, respectively. The columns to the right under 'Overestimated' and 'Underestimated' are similarly arranged. The last two columns of the table indicate respectively the totals of cases and that the percentages in each horizontal row total 100.

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[28] "Expectant attention" has been called a misnomer, since during the period of expectation the object to be attended to has not yet been cognized. But there seems to be no great difficulty concerning the connotation of the term. Cf., Pyle, W. H.: op. cit., 562-4, 569. Also footnote 32 on p. 39.

TABLE XIV

Data exhibiting differences in judgments of intensity of simultaneous pressure stimuli under different experimental efforts to control attention.

I. Continual effort to approach the thumb of the stimulated hand as near as possible to the first or third finger without actual contact.
II. Light momentary contact of thumb and finger at the time of a 2″ preparatory signal.
III. Effort to retain the pressure image of the prior pressure.
IV. Effort to visualize the finger and the areal contact resting upon it.

	True Cases %	Overest. Cases %	Underest. Cases %	Totals Cases %
I				
Observer D	20 (34)	31 (52)	8 (14)	59 (100)
" N	20 (33)	28 (47)	12 (20)	60 (100)
II				
Observer D	14 (23)	44 (73)	2 (4)	60 (100)
" N	17 (28)	37 (62)	6 (10)	60 (100)
III				
Observer D	21 (44)	19 (40)	8 (16)	48 (100)
" N	9 (23)	23 (57)	8 (20)	40 (100)
IV				
Observer D	36 (45)	21 (26)	23 (29)	80 (100)
" N	24 (30)	29 (36)	27 (34)	80 (100)

Repeated stimulation with the physically equal No. 3 pressures was the basis of the following accounts: (D). "Aim to follow changes in relative intensity and absolute intensity and discover conditions. *Absolute* intensity is not constant but swells and recedes.[29] The swelling condition is not clear. One receding condition is clear, i. e., active consideration of other matters, mechanical thinking connected with experiment or constructional thinking gives decreased intensity without prejudice to the left or right. Slight changes in position do not affect the change. *Relative* intensity (of left and right pressures) is not stable. Picturing the hand does not change the relative intensity regularly. Emphasis of consciousness of contacts, right and left, commonly does emphasize pressure stimulus on same side. In trying to 'feel-out' one side the other is astonishingly persistent; best feeling-out obtained by slight movement of the other hand, i. e., of finger against other—i. e., change."

(N.) "Observation of changes of relative and absolute intensity. Can decrease *absolute* intensity by thinking of other things, e. g., by reading or working out some problem. Sometimes it seems that I completely lose the stimuli. Other times they are merely noticeably less intense than when attention is directed to them. Accurate comparison seems impossible. *Relative* intensity: difficult to increase intensity of one pressure. The other pressure is very persistent. Effort to retain the pressure images of the involved hand seems introspectively to increase relative intensity of the corresponding pressure."

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[29] Drew noticed that under 'indifferent' attention "the intensities of each pair of stimuli differed subjectively, fluctuating capriciously both in degree and order." Op. cit., 545.

Results of Series 2. Because of the limited numbers of cases and observers, these results must be only tentatively accepted.

1. The upper six horizontal rows in the body of Table XIV show a strong tendency to overestimation of the pressure corresponding to attention, when a motor or the pressure-image method of detraction is used (i. e., method I, II, or III.)
2. The lower two horizontal rows of Table XIV show neither a tendency to overestimation nor underestimation when the visualization method is used (i. e., method IV). As already noted, method IV was found to be decidedly inadequate.

GROUP III.

The effort in all experiments of this third group was to ascertain the effect of attention on the stimulus limen.[30] Using an approximately threshold stimulus, would the number of stimuli judged superthreshold bear some relation to the degree of attention? In other words, would a pressure presented under attention be noticed a greater or smaller number of times than when attention was less favorable; or would differences in the conditions of attention be without effect?

The method aimed to present approximately liminal stimuli variously with three different degrees of attention. A subsequent comparison of the numbers of superthreshold cases falling in the respective categories should show any significant dependency on attention. The method was to create three different prestimulus situations which differed, among other things, in that they made the observer aware of the time at which the stimulus would occur with three different degrees of completeness. It is assumed that there were present in the observer in the prestimulus intervals corresponding differences in expectancy or readiness to receive the stimulus;[31] so that when the stimulus was presented there were corresponding differences in attention.[32] The prestimulus situations were, on the physical side, as follows: (1) no visual or auditory cue to the moment of stimulation; the observer's eyes were closed, (2) a momentary visual cue 1.7″ before stimulation, (3) observation of a moving signal lever which passes an index at the time of stimulation. Certain variants are indicated by the introspections below. (D.) 'Very hard not to 'see' (signal) lever with closed eyes (in situation I). Could not entirely dispel it.'

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[30] 'Superthreshold' and 'subthreshold' are not used in reference to systematically determined limina; but merely for brevity to indicate in describing the results whether or not the stimulus was experienced or 'felt.'

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[31] Experiments have already been made which probably prove that, under certain circumstances, the amount of attention at the time of stimulation depends on the length of the prestimulus interval. Aside from the evidence that a prestimulus interval of about two seconds is highly favorable, the argument is as follows: Dallenbach has conclusively shown a high correlation between degree of clearness and rate of sensory reaction. Breitwieser, Woodrow, Wells and others have shown a dependency between the length of prestimulus interval and reaction-time. Accepting clearness as a criterion of attention, there is hence probably a relationship between length of prestimulus interval and degree of attention. Our experiments virtually employ different lengths of prestimulus interval. Cf., Dallenbach, K. M., An Objective Measure of Attributive Clearness, Am. Jour. Psychol., 1918, 29, 204-7; Woodrow, op. cit., 16 ff.; Wells, F. L. and Kelley, C. M., On Attention and Simple Reaction, Jour. Exp'l. Psychol., 1921, 4, 391-8.

[32] In support of these assumptions may be cited Pyle's analysis of expectation, op. cit., 530-569. He has shown that expectation is characterized by readiness; and that the essential differences between expectation and attention are: (1) expectation has a future reference, while attention is all 'now'; (2) kinaesthetic and organic sensations are consciously primary in expectation, but in attention secondary to the image or perception in the focus; (3) there is no focus in expectation but only a mass of kinaesthetic and organic sensations of low clearness value; (4) in expectation, it is impossible to attend to the image of the coming impression, because we cannot attend to what is not in consciousness. If the stimulus were familiar, however, it seems that the observer might attend to the memory image. Cf. footnote 27, p. 35. "The bodily attitude is the same in expectation and in active attention." (563)

"The *expectancy* of change, in which attitude the observer finds himself, plays a part in the illusion, (of changed intensity) determining the tendency of the judgment." Arps, G. F.: Introspective Analysis of Certain Tactual Phenomena., Psychol. Rev., 1912, 19, 343.

Assuming that a state of expectation passes into a corresponding one of attention at the time of stimulation, is assuming no more than is done in the mass of attention experiments employing tachistoscopic exposure. Pyle showed that attention may pass into expectation (564). We assume that expectation may pass into attention. It seems introspectively clear that in our experiments, at the time of stimulation, there *does* occur the rise of clearness and focality of the stimulus, and the change from future reference to now. If this is so, our assumption is a valid one.

'Low respiration greatly aids getting the stimulus'[33] (N.) 'Tend to breathe synchronously with the (signal) lever—unintentional.' 'Sometimes expiring and sometimes inspiring when stimulus occurs, but no respiration during stimulation.'[34] 'When the eyes are closed, the respiration seems to be a difficulty.' 'Got rhythm in method I, and could tell when stimulus was coming.'

The observer was acquainted with his three different observational tasks, and he was warned prior to each change of the prestimulus situation. He was requested to report 'Yes' or 'No' according to whether the stimulus was super- or subthreshold. Of course in prestimulus situation I, when there was no visual or auditory cue, only the 'Yes' judgments were given.

Several modification in the apparatus were necessary. The moving parts were screened from the observer since we wished to control visual cues. Auditory cues were completely eliminated by the wearing of a wireless headset stuffed with cotton, and the noise of a fan motor. The momentary visual cue of situation II was produced by a slotted screen interposed between the observer's head and the signal lever which was reciprocated by the rotation of the crankshaft. The end of the lever could be seen through the slot when at its highest point. Stimulation occurred when the crank and lever were near their lowest positions. The duration of the time-interval between the visual cue and the stimulus was 1.7″. By means of a lever the experimenter could quickly move the screen to one side, bringing the complete signal lever into the observer's visual field. He could then observe the lever move toward its lowest position, as prescribed for situation III. At the moment of stimulation a marker attached to the lever passed a plain index projecting from a standard.

It was also necessary to make an adjustable stimulus weight, the base-form of which was similar to that of the original 10 g. lead weights. This weight could be hung in place of any of the original weights, and its magnitude adjusted by adding or removing small squares of sheet metal. These squares were slotted halfway across from one edge so that they could be slid on to the pin rising from the centre of the base. The mass of the base and pin was 2 g., and the mass of each increment (sheet metal square) was approximately 0.4 g.

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[33] The numerical results harmonize with this statement, in that they show more stimuli judged superthreshold when the respiration is low (i.e., shallow or depressed) than otherwise. There is experimental evidence that depressed respiration is a concomitant or factor of attention. Cf. Gamble, E. A. M., Attention and Thoracic Breathing, Am. Jour. Psychol., 1905, 16, 275, 277, 282. Stevens, H. C., A Plethysmographic Study of Attention, Am. Jour. Psychol. 1905, 16, 478, 480. Billings, M. L. and Shepard, J. F., The Change of Heart Rate with Attention, Psychol. Rev., 1910, 17, 227. Suter, J., Die Beziehung zwischen Aufmerksamkeit und Atmung, Arch. f. d. ges. Psychol., 1912, 25, 142.

[34] This was characteristic of N. in these experiments. A respiration pause seems to commonly occur in attention to a faint stimulus. Cf., e.g., Drew, op. cit., 556, 566. Gamble, Stevens, Suter, los. cit.

The area of stimulation on observer D. was the right third finger berry. This change from middle to third finger was made to obtain a surface of higher sensibility. Observer N's right middle finger was employed, as hitherto. The observer's position was as in Group II, except that only the right hand was supported in the apparatus. The interstimulation interval was 4″, and the initial weight was 10 g.

Temporally mixed by chance with every 5 stimuli were 5 zero 'stimuli' for control, making a set of 10. Eighteen such sets were prepared. It was then possible to run through a complete series, yielding 180 judgments, with no repetition of order. The three prestimulus situations were also mixed in each series, the mixing being in accordance with the linear permutations (of which there are six), in chance order. As to procedure; 5 stimuli, together with the 5 Vexierversuche, were presented in mixed order after one prestimulus situation, then likewise with a second, then with a third prestimulus situation. This resulted in 10 judgments corresponding to each situation or a total of 30 judgments, all obtained without removing or shifting the stimulated finger. Each prestimulus situation was used six times in a single series; consequently 6 x 30 or 180 judgments were obtained, as noted above. One series was the maximum experimentation for a single session. There were three series, yielding a total of 540 judgments for each of the two observers (D. and N.).

The data are arranged to show, comparatively, the percentage 'yes' (stimulus superthreshold) judgments after each of the three prestimulus situations.

The results of the three series in Table XV are similarly arranged. The differences in the conditions of these series are stated below the table. The first horizontal row across the top of the table gives the observers; the second row gives the numerals indicating the prestimulus situation. The vertical columns under the various mumerals contain the correspond-

TABLE XV

Pressure judgments made after three different prestimulus situations:
I. No visual or auditory cue to the moment of stimulation.
II. A momentary visual cue 1.7″ before stimulation.
III. Observation of a moving signal lever which passes an index at the moment of stimulation.

Observer	D			N		
Prestimulus Situation	I	II	III	I	II	III
Series 1						
No. of Stimuli	30	30	30	30	30	30
No. Superthreshold	4	16	23	14	25	26
% Superthreshold	*13*	*53*	*77*	*47*	*83*	*87*
M. V. (in % of Av.*)	100	37	23	33	7	21
Control Experiments Zero Stimulation	30	30	30	30	30	30
Judged Superthreshold Zero Stimulation	2	2	5	4	3	2
Series 2						
No. of Stimuli	30	30	30	30	30	30
No. Superthreshold	24	25	27	20	26	27
% Superthreshold	*80*	*83*	*90*	*67*	*87*	*90*
M. V. (in % of Av.*)	25	13	11	40	10	15
Control Experiments Zero Stimulation	30	30	30	30	30	30
Judged Superthreshold Zero Stimulation	1	1	1	2		1
Series 3						
No. of Stimuli	30	30	30	30	30	30
No. Superthreshold	12	21	23	20	24	28
% Superthreshold	*40*	*70*	*77*	*67*	*80*	*93*
M. V. (in % of Av.*)	16	19	23	30	8.3	9.4
Control Experiments Zero Stimulation	30	30	30	30	30	30
Judged Superthreshold Zero Stimulation	4	4		1	3	1

*This average is the average number superthreshold of 5 stimuli in 6 groups.

Series 1. Stimulus weight number 1 was employed. N. tended to observe with depressed respiration.

Series 2. Stimulus weight number 1 was employed, as in Series 1. D. and N. both observed with voluntarily (at first) depressed respiration.

Series 3. The value of the stimulus was reduced for each observer to bring it again close to the limen. This was accomplished by substituting for the number 2 weight the adjustable weight. Considered as at the area of contact, a decrement of .86 g. was necessary for D. and .73 g. for N. The value at the area of contact prior to decrement was 1.66 g. D. and N. both observed with depressed respiration, as in Series 2.

ing results. The first horizontal row of a given series contains the numbers of stimuli presented, that is, 30 for each prestimulus situation. The second row contains the numbers judged superthreshold, and the third the percentages derived from the two rows above, of the numbers judged superthreshold. The fourth row gives, for each prestimulus situation, the mean variation of the average number superthreshold out of the 6 groups of 5 stimuli each.[35] The fifth row contains the numbers of zero 'stimuli' or Vexierversuche intermixed with the stimuli of the first row, and the sixth or last row contains the numbers judged superthreshold or *Vexierfehler.*

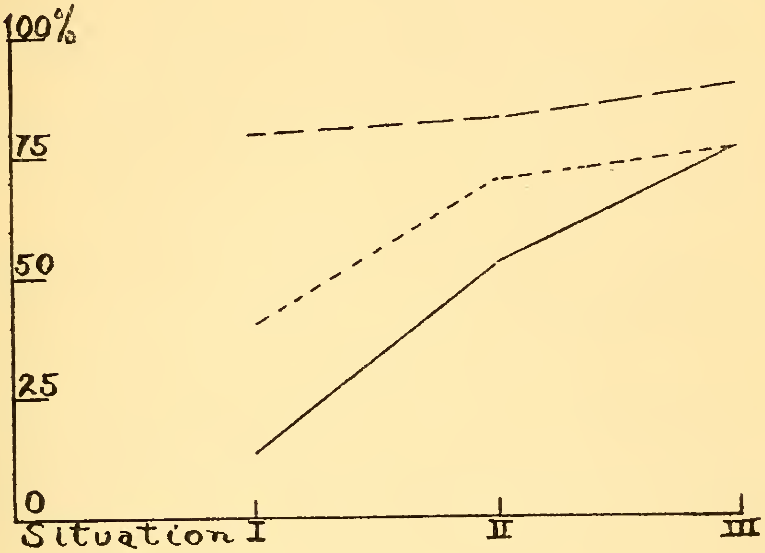

Fig. 7

Fig. 7 exhibits the data for D. in the third horizontal row for each series of Table XV; and shows the tendency for the number of stimuli judged superthreshold to vary with the favorableness of the attentional conditions. There is a separate curve for each series; for Series 1 it is a solid line, for Series 2 a coarse-broken line, and for Series 3 a fine-broken line.

Results of Group III.

1. Examination of the third horizontal row for each series shows that, for each observer, the number of stimuli judged superthreshold varies uniformly with the prestimulus situation. The more complete the observer's knowledge of the time of stimulation—the more favorable the attentional conditions—the greater the number of stimuli judged super-

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[35] All mean variations in both pressure and visual data were computed from two decimal places of the averages, which, for spatial economy, are omitted from the tables.

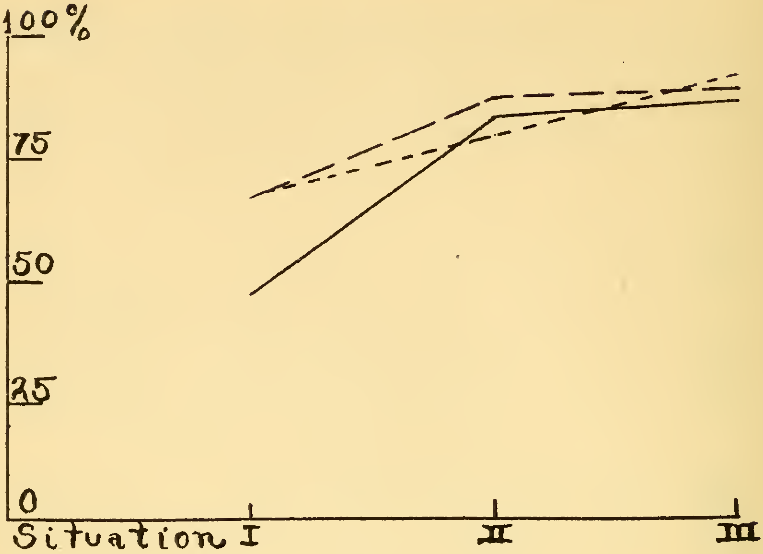

Fig. 8

Fig. 8 exhibits the data for N. in the third horizontal row for each series of Table XV; and shows the tendency for the number of stimuli judged superthreshold to vary with the favorableness of the attentional conditions. There is a separate curve for each series; for Series 1 it is a solid line; for Series 2, a coarse broken line; and for Series 3, a fine broken line.

threshold.[36] These results are graphically exhibited in Figs. 7 and 8.

2. The mean variation of the fourth row, in all cases except one, is larger with the first prestimulus situation than

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[36] In connection with these results we may note that Peters found that concentration upon a threshold impression was accompanied by increase in the number of times it was judged superthreshold. His problem was to measure attention by rise and fall in stimulus limen. Peters, W.: Aufmerksamkeit und Reizschwelle; Versuch zur Messung der Aufmerksamkeitskonzentration., Archiv. f. d. ges. Psychol., 1906, 8, 385-432, esp. 413 f.

In experimenting with the "fluctuations of attention to cutaneous stimuli," Geissler reported sometimes "introspections plainly show that the disappearance of the sensation is due to distractions which forcibly claim attention." Am. Jour. Psychol., 1907, 18, 314-5.

Vexierfehler—'errors' of judging double pressure when only one aesthesiometric point is in contact—have been shown to be increased through expectation. Cf., Henri, V. and Tawney, G. A.: Ueber die trugwahrnehmung zweier Punkte bei der Berührung eines Punktes der Haut., Phil. Stud., 1895, 11, 394-405.

In experimenting "on the 'after-sensation' of pressure," R. T. Holland found that "an after-experience (sensation) may arise under the influence of expectant attention." Jour. Exp'l. Psychol., 1920, 3, 317.

with the third situation. This seems to indicate greater stability if the time of stimulation is precisely known.

3. Comparison of the last two rows for each series shows that the percentages of 'stimuli' judged superthreshold when no stimuli were presented are small and show no tendency other than that they are smallest in the second series, which series contains the greatest number of stimuli judged superthreshold.

4. The note at the end of the table together with a comparison of the second horizontal rows of each series shows that, with depressed respiration, there is a larger number of stimuli judged superthreshold.[37]

SUMMARY OF RESULTS WITH INTERPRETATIONS FOR PRESSURE EXPERIMENTATION

The principal results under the experimental conditions are:

1. When two brief areal pressures occur successively on the same cutaneous area, there is a marked tendency to underestimate the second pressure. (Tables IV-VIII).

This result is opposed to the frequent tendency to overestimate the second stimulus (time error), in apparently analogous situations. We suggest that the tendency to underestimation shown in our results may be a fatigue-resultant. Perhaps the interstimulation interval was of insufficient length for complete recovery from the first pressure before the onset of the second pressure. Under such conditions the slight reduction in intensity necessary to produce an "underestimation" tendency would be ascribable to sensory fatigue.[38] It is noteworthy, on the other hand, that our photographic records show that the interstimulation interval was of sufficient length for recovery from the cutaneous deformation of the first pressure before the onset of the second pressure.

2. There is a somewhat greater tendency to underestimation of the second stimulus when using the larger (cf. p. 26) than when using the smaller stimulus increments. (Tables IV-VIII).

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[37] Cf. footnote 33, p. 40.

[38] Under certain conditions, when an auditory stimulus is preceded by a single brief stimulus, the first-mentioned appears to be less intensive than when presented alone. The effect is here ascribable to sensory fatigue. Cf., Flügel, J. C.: On Local Fatigue in the Auditory System, Brit. Jour. Psychol., 1920, 11, p't 1; and Newhall, op. cit., 233-5, 240. Brückner reported that with two pressure stimuli presented successively at an interval of 1-2", the intensity of the second sensation is reduced because of the peripheral fatigue induced by the first stimulus, op. cit., 42, 46, 54.

With regard to the suggestion concerning a fatigue effect, perhaps we should ordinarily expect a greater deformation to produce greater fatigue and possibly with the consequence that the second pressure would be, relatively, even less intense than when using the lesser stimulus increments, that is the lesser deformations; and hence even more "underestimated."

3. There are more false judgments for each observer except one when using the larger than when using the smaller stimulus increments. (Tables IV-VIII).

4. When two brief areal pressures occur simultaneously on the finger-berries of the left and right middle fingers, respectively, and attention is directed to a given hand; there is in general a tendency to relatively overestimate the pressure corresponding to the hand attended to. (Tables IX-XIII).

The tendency to overestimate seems to be due to increase (relative or absolute) in the intensity of the pressure sensation, due to attention.

5. While the distribution of the true and false cases is roughly the same for each observer, the distribution of the over- and under-estimations differs widely. (Tables IX-XIII).

We are inclined to believe that this instability is ascribable to the characteristic variability of attention.

6. The tendency to overestimation seems to be considerably affected according to the occupation of the observer (for detail, cf. p. 34-37) during the prestimulus interval. (Table XIV).

7. When an approximately liminal areal stimulus is presented, variously, after certain three different prestimulus situations, the number of stimuli judged superthreshold varies uniformly with the prestimulus situation. It appears to be true that the more complete the observer's knowledge of the time of stimulation, the greater the number of stimuli judged superthreshold. (Table XV).

As a result of the three different prestimulus situations the observer appears to receive the stimulus under correspondingly different degrees of attention; and we are inclined to believe that, under the conditions, the number of stimuli judged superthreshold tends to vary directly with the degree of attention.

8. When the approximately liminal stimulus is presented under depressed respiration, there are a larger number of stimuli judged superthreshold than otherwise. (Table XV).

This fact seems to indicate that depression of respiration causes a lowering of the threshold.

III. EXPERIMENTATION IN THE FIELD OF VISUAL BRIGHTNESS

The visual experiments are concerned with the effect of attention on brightness when the stimulus is at approximately the difference-limen. The method in general consists in the observation of the brightness under different conditions of attention. As in the pressure experiments, the matter of stimulus-control will be considered at the first; while the several means of attentional control will be stated in connection with the corresponding experimental series.

It is to be emphasized here that there is no intention to imply that the brightness series is a purely quantitative series. Indeed, the consensus of the literature would seem to point in the other direction.[39] Brightnesses were used in these experiments because they are probably the least objectionable material for the problem to be found in the field of visual sensation in general.

The Exposure Apparatus and the Characteristics of the Stimulus

The visual apparatus was set up with the intent to meet the following requirements: (1) The production of a momentary brightness-increase of limited area on a constant-brightness field, (2) The possibility of easy presentation or non-presentation of the stimulus (corresponding to the momentary brightness-increase), (3) The possibility of executing (2) at a predetermined constant rate, i.e., with equal interstimulation intervals, (4) The possibility of easy presentation or non-presentation of a momentary auditory stimulus simultaneous *with* the visual stimulus, or without the visual stimulus.

(1) The apparatus consisted of the older form of the Dodge mirror tachistoscope,[40] together with the accessories necessary for adapting it to the present purposes.

Figure 9 is semi-diagrammatic and shows the approximate

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[39] E. G., Kuelpe; Outlines of Psychol. (tr.) N. Y., 1895, 113, 119 f. Ladd and Woodworth; Elements of Physiol. Psychol., N. Y., 1911, 354 f. Titchener; Textbook of Psychol., 1919, 204-6.

[40] Dodge, R.: An Improved Exposure Apparatus: Psychol. Bull., 1907, 4, No. 1, 10-13.

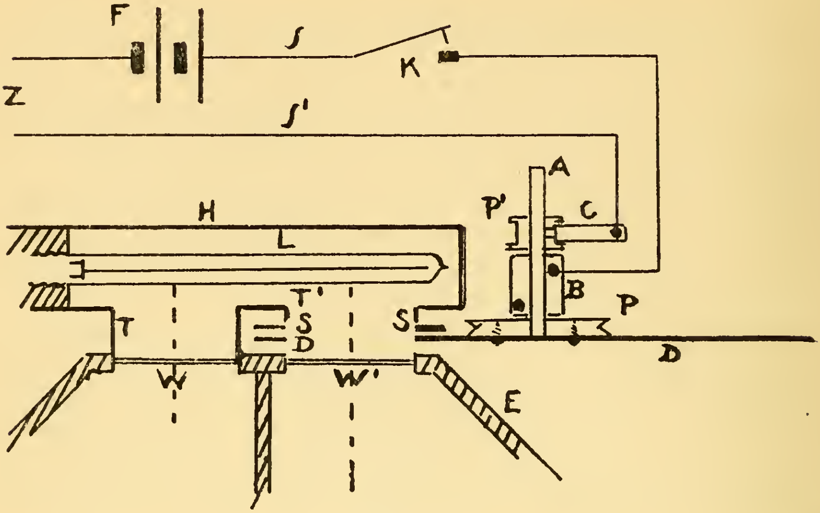

Fig. 9

spatial arrangement of the parts accessory to the tachistoscope. The figure represents a horizontal section through the apparatus at the level of the centers of the tachistoscopic windows, W and W′. The tachistoscope was rigidly mounted at one end of a heavy table at such a height that the hood came at the level of the sitting observer's eyes. It was not found necessary to make adjustments for individual differences in sitting-height; the same chair was used for all. The source of light was a long single-filament, 40 watt showcase lamp, L, by Westinghouse. This lamp was enclosed in a horizontal sheet-metal housing, H, 5 × 5 × 30 cm., one face of which lay in a plane parallel to the plane of the adjacent windows, W and W′, of the tachistoscope and removed from it by approximately 2 cm. The filament of the lamp passed the centre of each window. Opposite each window, which is 5 cm. square and glazed with ground glass, an aperture also 5 cm. square was cut in the wall of the lamp-house. One aperture was directly connected with the window opposite by a sheet-metal tunnel, T, whose cross-section was 5 cm. square. The entire area of the window was illuminated, and the flux through it fell upon the permanent exposure field. The other aperture also formed the origin of a tunnel, T′, 5 cm. in cross-section, but it was only about one cm. in length and terminated in a slot lying in a vertical plane. This slot, which was ca. 2 cm. vertically and 5 cm. horizontally, was cut in the centre of a metal facing which otherwise completely covered the end of the tunnel.

The flux through the window opposite the latter or shorter tunnel, T′, could be adjusted by varying the width of the exposed strip of ground glass at the centre of the window, W′. This could be done with black metal shutters (not represented in the figure) sliding snugly over the exterior surface of the glass. The width of the exposed strip (its length remained constant at 5 cm.) could be read off or precisely adjusted by means of an index fixed to the tachistoscopic casing, E, and a millimetre scale on one of the shutters. The flux passing through the ground glass served to illuminate the stimulus-object.

In the narrow space between the slot in the end of the tunnel and the strip of exposed glass in the tachistoscopic window, there was a vertical screen, S, in which was a slot, S, of the same dimensions as that at the end of the tunnel. When the slot of the screen was in register (as in the figure) with that of the tunnel-end, light could pass through it and the ground glass window into the tachistoscope. A sufficient vertical movement of the screen would throw the slot out of register and cut off the light to the tachistoscope. This constituted an exposure screen.

(2) It was necessary to devise a means of rapid and noiseless manipulation of the exposure screen for the presentation or non-presentation of the stimulus. To this end the exposure screen was mounted on a double lever device (not represented) which constituted with the screen a parallelogram and held the screen accurately, close to the opening of the light tunnel without the possibility of scraping. A manipulating key was made by attaching an offset from this screen-lever parallelogram to a light key lever in convenient position for the experimenter. The details of the construction are as follows: Two 25 cm. light wooden strips were respectively pivoted to the middle points of the upper and lower edges of the screen. The strips, when in position, lay in a plane perpendicular to that of the screen; in other words, they extended away from the window of the tachistoscope. The strips were held parallel with each other by another strip which was the same length as the height of the screen and was joined to the strips to form a jointed parallelogram. In order to bring the screen into position, the jointed parallelogram was mounted on a suitably

placed vertical standard, by passing pins through the upper and lower strips into the standard. The distance between the standard and the screen was 13 cm. The lower strip projected about 5 cm. beyond the connecting strip and the end of the former was hinged to the upper end of a vertical stiff wire rod. The lower end of this rod was hinged to a long, light lever, the manipulating key, at a point not far from its fulcrum. The axis was horizontal and consisted of nicked knife-edges, the stationary set being screwed to the table. The movable knife edges and the lever were held in normal position by rubber bands. Felt strips on the stops insured noiseless operation of the lever. With the lever in normal position, the slot of the screen would be wholly out of register. Depression of the lever would cause the jointed parallelogram to raise the screen vertically and bring the slot wholly into register (as in figure). Since the screen and tunnel-slots were much wider than the exposed strip of ground glass, the flux through the latter and consequently the intensity of the resulting tachistoscopic stimulus-illumination, depended solely on the width of the strip of ground glass. The various widths used were 6, 8 and 10 mm.

(3) With this exposure screen there was now available the means of temporarily illuminating the stimulus object; but it was necessary to control the duration of exposure more precisely than it would be possible to do by the direct manipulation of the long lever. To this end a sheet metal disc, D, of 12.5 cm. radius was prepared; and part of an internal sector with a radial length of slightly over 5 cm.—that is, slightly longer than the exposed ground glass strip—was removed. The outer arc of the sector was separated from the circumference of the disc by 2.5 cm. The arcs bounding the removed portion of the sector were 36° or 1/10 of 360°. The disc was counterbalanced to compensate for the removed area. It was accurately centered and screwed to the face of a grooved wooden pulley, P. The pulley itself was mounted at one end of a steel shaft, A, which turned smoothly in a long brass bearing, B. The bearing was so placed with reference to the tachistoscope that the disc, D, lay in a plane parallel to and between the planes of the parallelogram exposure screen and the tachistoscopic windows, and so that the open part-sector would register (as in figure) with the exposed ground glass strip once per revolution. This registration would occur when

the open part-sector lay in the horizontal diameter of the disc. The disc was driven at a speed of approximately 60 R. P. M. by a constant-speed electric motor. Since the open part-sector measured 36° the time interval during which the disc did not cover the glass strip was approximately 0.1″ per revolution.

If now, the experimenter depressed the screen-lever at some time when the open part-sector was not at the window and held it until after the passage of the sector, a closely controlled exposure (stimulus) of 0.1″ would be made. By continued depression of the screen lever the experimenter could make a series of exposures, the onsets of which would be 1″ apart; or by continued non-depression there would be a corresponding interval of non-stimulation.

(4) The experiments employed an auditory stimulus signal which was the click produced by a 4.5 cm. watch-case buzzer, Z—open. In order that a click rather than a buzz would be produced, the magnets were connected directly across the binding-posts of the instrument. It was situated in the approximate sagittal plane, 60 cm. in front of the aural axis. In series with the buzzer-magnets was a dry battery of two cells, F, a mercury key, K, and a contact, C. The latter was the means of simultaneous presentation with the visual stimulus and was arranged as follows: one lead, l, terminated in a binding-post on the brass bearing-block, B, of the disc-shaft, while the other was connected to a brush, C, bearing a silver contact-area. This contact played on the circumference of a small hard rubber disc, P′, driven tightly on the end of the disc-shaft. A brass pin (represented as in contact with the brush) extended radius-like from flush with the circumference of the small hard rubber disc to contact with the shaft at the centre. Consequently, when the brush pressed on the end of the brass pin, providing the mercury key was closed, the circuit was closed and the buzzer clicked. The contact of pin and brush was arranged to occur (as indicated in the figure) when the open sector of the sheet-metal disc was in full register with the exposed ground glass strip of the tachistoscopic window.

By closure of the mercury key and depression of the screen-lever, it was now possible to present the auditory and visual stimuli simultaneously. It is obvious that either stimulus, or both, could be omitted by omitting, variously, to depress the key, the lever, or both.

The light entering the wholly open window, W, as stated above, served to illuminate the permanent exposure field. The surface was white drawing paper and at its centre was drawn a grey-line fixation object consisting of an 8 mm. square containing two lines crossing at the centre. One cross line was horizontal and the other was vertical. The distance from the eyes was approximately 35 cm.

The light through the partially closed window, W′, that is, through the exposed strip of ground glass, illuminated the stimulus object. This object was white drawing paper in the form of a 5 mm. square on a dead black ground. It was so placed that when viewed tachistoscopically at a sufficient illumination, there would momentarily appear a square of increased brightness within the square fixation object. There was no experimental modification in the illumination on the permanent field.

It was found desirable to concentrate the light passing through the partially closed window upon the 5 mm. stimulus area for two reasons, (1) so that the illumination of the stimulus area would be sufficiently intense without making the window opening unduly wide, and (2) to aid in eliminating secondary visual cues. In preliminary trials peripheral flashes simultaneous with the time of the stimulus had been observed. These were found to be due to stray rays on the stimulus side of the tachistoscope. So the concentration was raised by replacing the regular silvered-glass plane mirror with a "concave" one formed of three plane-mirrors. This led to increased brightness but did not wholly cut out the peripheral flashes. The latter were eliminated by setting up black cardboard screens in the tunnel between the window of the tachistoscope and the "transparent" mirror. Care was taken to eliminate all irrelevant tactual and auditory cues as well.

The room in which the apparatus was set up was artificially lighted at a moderate and nearly constant intensity during the experimental sessions. This was the only means used for controlling the pupillary diameter, which has been shown to be a significant factor in the intensity of retinal stimulation.[41] Consequently we cannot state the value of the retinal stimulus, but that seems unnecessary in view of the main problem.

The nature of the stimulus may be physically expressed in terms of the intensity of illumination of the white drawing paper fields as *seen through the transparent mirror* at the position of the observer's eyes. With the barrel of the photometer at the position of one or the other eye, series of measurements were made of the permanent exposure field and of the various approximately liminal stimulus-increments used. The summarized results are given in Tables XVI and XVII.

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[41] Troland, L. T.: On Measurement of Visual Stimulation Intensities; Jour. Exp'l. Psychol., 1917, 2, 1ff.

TABLE XVI

Photometric estimations of intensities of illumination

Observers	D	F	N	W
Width of Aperture, mms.	10	8	6	6
Illumination of Permanent Field, F.C.	1.26	1.26	1.26	1.26
Stimulus Increment, F. C.	.0375	.0315	.0225	.0225

The above figures are the averages of 10 observations under each set of conditions or a total of 40 observations. The M. V's range from 7% to 15% of their averages. F. C. = foot candles.

TABLE XVII

Successive series of observations with successive settings of the aperture at a given width, for the purpose of showing any significant effect due to inaccuracies of setting.

Series	1	2	3	4	Aperture
Stimulus Increment, F. C.	.0315	.0340	.0325	.0340	8

The above figures are each averages of 10 observations. The maximum difference between any two of these averages is 8% which is no larger than the M. V.'s of the individual series. Inaccuracies of aperture-setting are consequently regarded as of no significance.

The instrument employed was an equality-of-brightness portable photometer imported by the J. G. Biddle Company. It had recently returned to the Physical Laboratory from the Bureau of Standards where it had been tested and calibrated.

Introspection reported during the visual experiments gives an indication of the nature of the brightness resulting from the momentary visual stimulus. (D) 'Memorandum: The square patch is seldom visible, with 10 mm. aperture, as a full square. One quadrant is commonly emphasized. The rest is either fainter or occasionally invisible. It gives the illusion of movement, or jumping about. No *obvious* explanation of why any particular quadrant is selected. It is not fixation. When attending to them and often otherwise, I see negative after images of the light patch. The after images are always quite complete squares, full size in proper position. They last

1-2 seconds. They are occasionally the only knowledge of the exposure, i.e., I have occasionally seen them but not the exposure white.' 'Curious dark shadows which I have mentioned before as probably the negative after image of subthreshold stimulus; full patch-size. Lasted about 1—1 and 1/2 seconds.' (F) 'Sometimes looks like a little circle at the cross-hairs. Other times I see it in various quarters (of the fixation square) ; tends to be to the right. When it is dim it is a portion of a circle (i.e., portion of a circular area). When it is bright it looks like a clean-cut circle (that is) a small bright area circular in form.' 'Exceptionally bright field tonight.' 'Whole field seemed distinctly whiter than usual (this session). It is sometimes yellowish.' (N) 'I get the brightness-patch at different intensities, in various positions and degrees of clean-cutness of form. Negative 'after images of the crosslines.' 'Occasionally got negative after images of the centre vertical of the fixation object—on each side of it. Slightly troublesome.' 'Whole field seemed to fluctuate in brightness during the last series (i.e., last half of the session).' 'Noticed that my sensitivity seems greater when I do not strain to see, as in distant vision of minute objects. I can see best when I look blandly at the cross hairs with eyes rather wide open.' (W) 'Get the flash always in the same place, i.e., in the upper quadrants and close to but on each side of the vertical line.' 'The outline is not clean cut at the lowest intensities (the intensities were physically unchanged,) but becomes more so at higher intensities.' 'At the higher intensities the spot seems to be a rather clean-cut circular affair' whose centre approximately coincides with the centre of the fixation object.' 'At the lower intensities it is simply a flash in the upper two quadrants' as noted above. On one occasion the sensitivity of W. seemed remarkably low; even when the width of the aperture was increased beyond his regular figure, the stimulus was only occasionally superthreshold whereas ordinarily it was commonly so. Since, in addition, the observer reported general fatigue the regular experimental session was omitted on that day.

In general it may be said that the stimulus gave rise to a momentary brightness-increase which was always wholly confined within the fixation object. Its form was usually of indefinite boundary; but it varied for each observer, under individually constant physical conditions, through different degrees of vagueness of outline to a relatively bright, clean-cut area. It seems that the vagueness of outline varies with the brightness. The brightness change appeared, at different times, in different quadrants of the fixation object. Irrespective of the outline, the quality of the various brightnesses seemed to be the same. The observers apparently became very largely adapted to the yellowish hue of the Mazda light. As in the pressure experiments, the sensitivity seemed to be noticeably different in some experimental sessions than in others.

Procedures and Results

Summary

(a) Comparison of judgments of an approximately difference-liminal, momentary, visual stimulus after three pre-stimulus situations favoring, respectively, different degrees of attention at the time of stimulation; indicates that there is a weak tendency for the number of superthreshold stimuli to vary with the presumptive degree of attention. The momentary visual brightness tends to vary in degree according to the presumptive degree of attention. (pp. 55-62, 69-71).

(b) Comparison of series of five momentary visual stimuli of uniform physical and approximately difference-liminal value which are presented respectively with five simultaneous clicks, with series in which the clicks are omitted; shows the tendency for more stimuli to be judged superthreshold and the magnitude of brightness to be judged greater, when the clicks are given. (pp. 62-69, 71).

GROUP I.

The effort in all of these experiments was to ascertain whether or not attention lowered the difference-limen. The experimental question was, using a stimulus of approximately difference-threshold value, would the number of stimuli judged superthreshold bear some relation to the degree of attention?

The method is similar to that of the liminal pressure experiments of Group III. In this visual group we worked near the difference-limen instead of the stimulus-limen because the latter seemed impracticable. The aim was to present stimuli of approximately difference-threshold value variously with three different degrees of attention. The method was to create three different pre-stimulus situations which differed among other things in that they made the observer aware of the time at which the stimulus would occur with three different degrees of completeness. It is assumed that there was present in the observer in the prestimulus intervals a corresponding difference in expectancy and readiness to receive the stimulus (this is introspectively true); so that when the stimulus *was* presented there were corresponding differences in attention.[42] The prestimulus situations were, on the physical side, as follows: (I) An auditory click followed by a 9-second prestimulus interval in which the first 5 seconds are estimated by counting; (II) a series of 5 clicks falling on successive seconds and followed by a 4-second prestimulus interval; (III) a series of 5 clicks falling on successive seconds with presentation of the stimulus on the sixth second. In connection with these methods it may be noted that dryness of the eyes, muscle-twitching, strain, and strain and pain from refraining to wink were but infrequently reported.

The observer was acquainted with his three different tasks and he was warned prior to each change of the prestimulus situation. The instructions were as follows: "(I) You will hear a preliminary click. You are to fixate the crosslines on the permanent exposure field, and judge whether or not there is an increase in brightness within the square about the tenth second or when experimenter says 'report.' Estimate the first 5 seconds by counting and wink on the fifth second but not thereafter. Do not count seconds to estimate the time after fifth second. From the time of the initial click keep the eyes open (except for wink) and directed to the fixation mark until experimenter says 'report.' Report 'Yes' if you saw an increased brightness—otherwise 'No.' (Try to estimate the intensity of the brightness on a scale of five. Let 'one' be just barely observable brightness and '5' half again the brightness of the permanent exposure field. (This instruction is to be introduced after 30 experimental judgments have been made.)) (II) You will hear a series of 5 clicks and you will count them and wink slightly on the fifth but not thereafter. You will fixate as in I, and make judgment about the fifth second or when experimenter says 'report.' (III) You will hear a series of 5 clicks. You will not wink after the second click. You will fixate as above and make judgment about one second after the fifth click." Observers D. and N. did not have the winking instructions until after making their first 60 experimental judgments each.

The procedure was parallel to that of the liminal pressure experiments of Group III. Temporally mixed by chance with every 5 stimuli were 5 zero 'stimuli' for control, making a set of 10. Eighteen such sets, all different, were used. It was then possible to run through a series of experiments, yielding 180 judgments, with no repetition of order. The three prestimulus situations were also mixed in each series, the mixing being in accordance with the linear permutations, in chance order. As to experimental procedure: 5 stimuli together with the Vexierversuche, were presented in mixed order after one prestimulus situation, then likewise with a second, then with a third prestimulus situation. This resulted in 10 judgments corresponding to each situation or a total of 30 judgments, all obtained without withdrawal of the head from the hood. Each prestimulus situation was used twelve times (that is the chance cycle was once repeated) ; consequently 12 × 30 or 360 judgments were obtained. Thirty judgments was the maximum for a single day's experimentation. The time required was 7-10 minutes. Each of the four observers made a total of 360 judgments.

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[42] Cf. footnotes 31 and 32, p. 39.

After the first experimental session for each observer during which unmistakable fluctuations in the brightness were observed, it was found possible to roughly estimate the observed magnitudes on an arbitrary scale of five units. Just barely observable brightness was given a value of unity, and half again the value of the permanent field was designated "5." The latter was 'quite bright' and of sharp outline. Observers D. and N. soon formed the habit of denominating the very slightest brightnesses 'one-half.' Observers F. and W. were given no instruction to do this until the beginning of the experiments of Group II, and consequently continued to call the least perceptible differences "one." It is to be emphasized that these brightness-estimates must be looked upon as *rough*. That there were real differences is unmistakable. The criteria below were reported in Group II. (D) He judges the "one-half" brightness by a partial contourless change. If it has contour he calls it "one." "'One-half' includes any flicker in the field up to an obvious change in brightness without contours." (F) 'One-half are a flash in one quadrant or across diagonally in two.' 'One is apt to be an irregular area generally in all four quadrants.' 'Two and three are distinctly a circular area of brightness.'

A preliminary test was made at the beginning of each experimental session, and was in most cases repeated at the end of the session. The observer was presented with a series of 10 stimuli simultaneous with 10 clicks. The intraserial intervals were one second. If the observer could barely perceive each brightness or at least seven of them under these conditions of high emphasis, the experimental sub-series of 30 was commenced. If more than three of the preliminary stimuli were subthreshold, the series of 10 was repeated. The observer usually found 7-10 stimuli to be superthreshold within several trials. Only twice after the preliminary experiments of the visual investigation as a whole, was it found necessary to alter the width of the tachistoscopic stimulus-window. The changes were for observer F., i.e., 8 mm. to 10 mm. for one session only, and then back to 8 mm. again.[43] A study of the introspection shows that both the pre-and post-experimental trials vary widely as regards the number of stimuli noticed, the brightness-values, and their distribution.

The data were arranged to show, comparatively, the percentage 'Yes' (stimulus superthreshold) judgments after each of the three prestimulus situations.

The results of this group are given in Table XVIII, which is constructed in nearly the same way as Table XV, page 42. The first horizontal row across the top of the table gives the observers; the second row gives the numerals indicating the prestimulus situations. The vertical columns under the various numerals contain the corresponding results. The first horizontal row of the body of the table contains the numbers of stimuli presented, that is, 60 for each prestimulus situation. The second row contains the numbers judged superthreshold, and the third the percentages, derived from the two rows above, of the numbers judged superthreshold. The fourth row gives, for each prestimulus situation, the mean variation of the average number superthreshold out of the 12 groups of 5 stimuli each. The fifth row contains the averages of the estimated brightnesses. These averages are based on the numbers of superthreshold cases which are given in the second row of the body of the table. The sixth row gives the corresponding mean variations. The seventh row contains the numbers of zero 'stimuli' or Vexierversuche intermixed with the stimuli of the first row, and the eighth or last, the numbers judged superthreshold or *Vexierfehler.*

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[43] On the day of the 10 mm. aperture he remarked that he had just come from the swimming pool which often contains an unpleasantly strong chemical solution.

TABLE XVIII

Brightness judgments made after three different prestimulus situations:

I. An auditory click followed by a 9 second prestimulus interval in which the first 5 seconds are estimated by counting.

II. A series of 5 clicks falling on successive seconds and followed by a 4 second prestimulus interval.

III. A series of 5 clicks falling on successive seconds with presentation of the stimulus on the sixth second.

Observer	D			F			N			W		
Prestimulus Situation	I	II	III	I	II	III	I	II	III	I	II	III
No. of Stimuli	60	60	60	60	60	60	60	60	60	60	60	60
No. Superthreshold	22	25	41	37	47	44	32	30	44	24	20	22
% Superthreshold	*37*	*42*	*68*	*62*	*78*	*73*	*53*	*50*	*73*	*40*	*33*	*37*
M.V.(in % of Av.*)	38	45	22	36	24	33	44	43	29	50	78	39
Av. Estimated Br'tness	*.95*	*.98*	*1.5*	*1.1*	*1.1*	*1.8*	*.90*	*1.3*	*1.9*	*1.1*	*1.1*	*1.0*
M. V. (in % of Av.*)	37	21	59	17	18	45	34	49	45	15	18	
Control Experiments												
Zero Stimulation	60	60	60	60	60	60	60	60	60	60	60	60
Judged Superthreshold												
Zero Stimulation	2	2	3					2		10	9	6

*This average is the average number superthreshold of 5 stimuli in 12 groups.

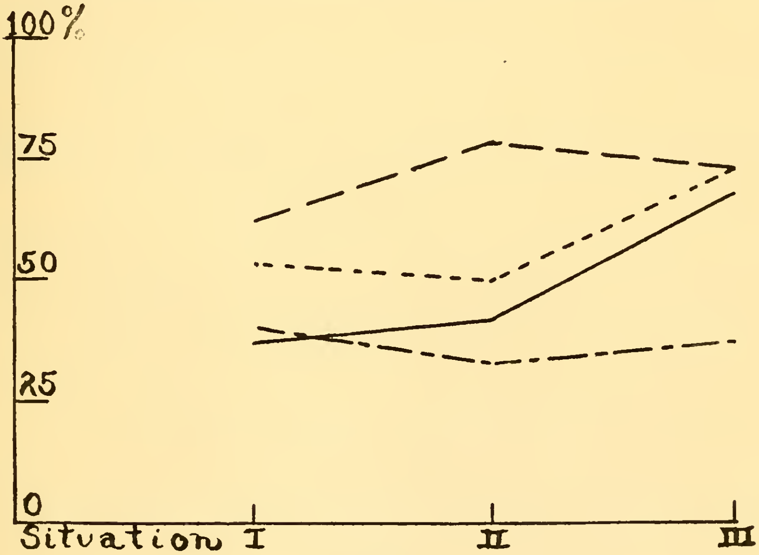

Fig. 10

Fig 10 exhibits the data for D., F., N. and W. in the third horizontal row of the body of Table XVIII; and shows the weak tendency for the number of stimuli judged superthreshold to vary with the favorableness of the attentional conditions. There is a separate curve for each observer; for D. it is a solid line, for F. a coarse-broken line, for N. a fine-broken line, and for W. mixed coarse- and fine-broken.

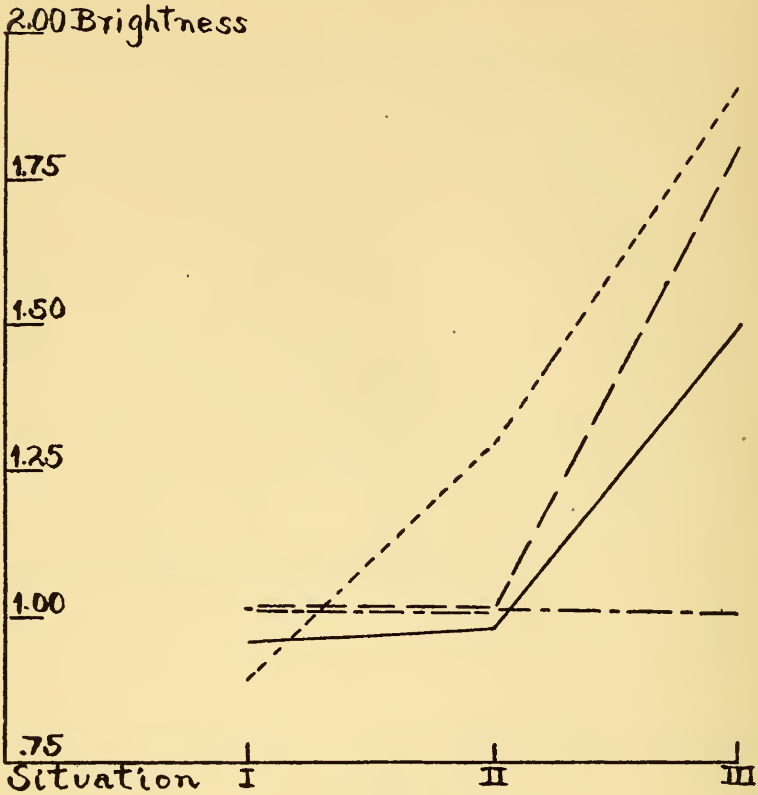

Fig. 11

Fig. 11 exhibits the data for D., F., N., and W. in the sixth horizontal row of the body of Table XVIII; and shows the tendency for the degree of brightness to vary with the favorableness of the attentional conditions. There is a separate curve for each observer; for D. it is a solid line, for F. a coarse-broken line, for N. fine-broken, and for W. mixed coarse- and fine-broken.

The two following incidents seem significant. (F) In about 20 successive preliminary trials during which the simultaneous auditory clicks were omitted, F. could see no brightness-change in the field. The experimenter then started to give the clicks. After 8 to 10 stimuli F. asked to have the clicks stopped and this was done. Not until later did the experimenter ask F. why he wished the clicks stopped. He replied that he had experienced a 'brightness-fluctuation with each click' and that the fluctuations were 'illusory and due to the clicks,' and that he consequently thought they 'ought not to count.' He further said that he ceased to experience the fluctuations as soon as the clicks were discontinued. It seems to us that these results, which are obviously 'without knowledge,' point toward facilitation depending on the auditory stimuli.[44] (W.) By mistake W. was presented with the visual stimulus on each of the five last seconds (prestimulus situation II.) but he merely judged the stimulus superthreshold once, i.e., he noticed but one stimulus of the five presented under the same physical conditions. He was apparently set to receive but the one stimulus as according to normal procedure.

Results of Group I.

1. Examination of the third horizontal row in the body of the table shows that observers D., F. and N. judged more stimuli superthreshold after the third prestimulus situation than after the first; that observers D., N. and W. judged more superthreshold after the third than after the second situation; and that observers D. and F. judged more superthreshold after the second than after the first situation. There is consequently indicated somewhat of a tendency for the number of stimuli judged superthreshold to vary with the prestimulus situation. These results are graphically exhibited in Fig. 10.

2. The mean variation of the fifth row is in all cases larger with the first prestimulus situation than with the third situation. This seems to indicate greater stability if the time of stimulation is precisely known (as it is, when the third situation is used).

3. The "average estimated brightness" of observers D. and N. varies uniformly with the prestimulus situation; the average brightness of observer F. is equal in the first two situations and greater in the third; and the average brightness of W. is equal in the first two situations and slightly less in the third. There is consequently indicated a tendency for the brightness to vary with the prestimulus situation. These results are graphically exhibited in Fig. 11. The mean variations of these averages tend to be largest in the third situation.

4. The last two rows in the table show that the percentages of 'stimuli' judged superthreshold when no stimuli were presented are small, except for W. and show no particular distributional tendency. All were reported as of the lowest order of brightness. We have no explanation for the relatively large

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[44] It is interesting to note that Arps remarked 'assimilation' between visual and auditory sensations, op. cit., 345, 347.

number of *Vexierfehler* in W.'s case. But his results have deviated markedly in two other researches from those of the other observers, which seems to make him an interesting problem in human variability.

GROUP II

The aim in these experiments was the same as in those comprising Group I, i.e., to ascertain whether or not attention lowers the limen, or in other words whether or not the number of approximately liminal stimuli judged superthreshold bears some relation to the degree of attention. The utilitarian purpose was to check the validity of the results of Group I.

The method was different from that of the preceding experiments, but its aim was similar, i e., the presentation of stimuli of approximately difference-liminal value with different degrees of attention. The method for the experiments comprising Series I was suggested by incidental results in connection with Group I. In the latter each experimental session was prefaced and usually concluded with a test experiment, already mentioned. It consisted in the presentation of a series of 10 visual stimuli together with 10 clicks, each click being simultaneous with a visual stimulus. In a number of cases, under apparently favorable conditions, the observer had failed to notice the first several visual stimuli. Since we had no good reason to expect that this was an affair of peripheral accommodation or adaptation, we decided to investigate it, and by the following method. The observer was given a 3-second ready signal, and then a series of 5 approximately liminal visual stimuli with simultaneous clicks, occurring on successive seconds. He reported the stimuli judged superthreshold in terms of the digits representing their temporal positions; the first stimulus was denominated 'one,' the second 'two,' and so on. Since all clicks were superthreshold, the observer could report the correct numbers for the superthreshold visual stimuli even though some of the visual stimuli were subthreshold. The point was to see whether or not there was a relatively regular distribution of superthreshold stimuli throughout the series of five, and if not, to ascertain the form of the distribution. Our incidental observations had revealed an occasional lack of superthreshold judgments at the first of the series, which might or might not be significant.

The method of Series 1 was also used in Series 2 except for the important difference that in the latter the clicks occurring simultaneously with the visual stimuli were omitted. The experiments of this series were made for the purpose of finding out, in conjunction with the results of Series 1, if there were more or less stimuli judged superthreshold when the clicks were given as compared with when they were omitted. The introspection of F (p. 60) had seemed to point to a dependency between the giving of the clicks and the number of superthreshold visual stimuli. In both series, as in Group I, the observers estimated the magnitudes of brightness on the scale of five. Before these series all observers had been requested to denominate the only just observable brightness "one-half." This means that in these experiments there was the same number of values in the judgment-scale of each observer, the values being ½, 1, 2, 3, 4, 5.

The following accounts, given after the experiments were over, refer to introspective differences ascribable to the use and omission of the clicks. (F) 'The clicks seemed to be of convenience. Know the stimulus is coming with the click; gives attitude of assurance. The clicks do not seem to have any effect on the brightness.' F. counted out the stimuli in the series without the clicks, and the 'rhythm of counting seems to have no effect on the brightness. All that the rhythm or counting does is to put the observer more at ease. Felt better prepared to receive the stimuli when the clicks were given.'[45] Sometimes in the clickless series F. did not pick up the rhythm until after the first several stimuli. He noticed respiration 'through both series' and seemed to be breathing normally all the time. (W) 'There is a feeling of relaxation, confined to the eyes, between clicks and concentration on the field at the time of click.[46] 'The click is indifferent as regards distraction. The *periodicity* established by the click is what counts, not the click.' The periodicity is present in clickless series if he gets the first two or three flashes. He always gets *series* of successive flashes, not a break and then more flashes; in other words the subthreshold stimuli occur either at the beginning or end of the series of five. The rhythm seems to raise the stimulus above the threshold, but does not then increase the brightness. W. felt 'pretty sure that respiration is normal' and that there was no rhythmic relation between it and the stimuli.

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[45] Using a constant brightness during a series of five hammer strokes about two seconds apart, Arps noted fluctuations in the visual judgments corresponding to the series of five sounds; and he concluded that the rhythm has its effect in other departments than that of the sense receiving the series of rhythmical stimuli. (511, 528) He noted that a periodic stimulus is especially favorable to attention. (505) Der Verlauf der Aufmerksamkeit bei rhythmischen Reizen., Psychol. Stud., 1909, 4.

[46] See footnote 45, above.

The following introspections of observers D. and F. are interesting because of the apparent similarity of the reported experiences. (D) Series 2: "Got the throb of the light with no clear distinction between areas. It pulsated. I should probably not have called that pulsation under old conditions (Series 1). Pulsation without apparent differences in illumination. No contours. Called them 'one-half.' Good many of the 'one-halves' were of that character." "If one gets the rhythm the sequence of flashes becomes quite clear, i. e., superthreshold. If one fails to get the rhythm, getting a flash is apparently a matter of accident."[47] (F) He designated some of the extremely faint flashes 'one-quarter.' "One-quarter have no outline, form, space, or location—just know they are there. Seems same as 'one-half' only less intense. There is no particular point where the light can be said to increase. There is a fluctuation of light."

The instructions were as follows: Series 1. "(1) You will receive a 'ready' signal and 3 seconds thereafter will begin a series of 5 clicks. (2) Fixate the crosslines and do not wink more than one second after the 'ready' signal. (3) After the series of clicks, report whether or not there is a momentary brightness increase simultaneous with each click, indicating the temporal order. Estimate the magnitudes of brightness on the scale of five." Series 2. "(1) No clicks will be given in this series. (2) You are to judge as in Series 1. When E says 'report' indicate temporal order and degree of brightness."

Series 1 and 2 each contained 100 single experiments, i. e., 100 series of 5 stimuli, which in Series 1 were presented with simultaneous clicks. For observers D. and N., Series 1 preceded Series 2. Table XXIII shows that their results were somewhat affected by a negative practice effect. For observers F. and W., the series were mixed. As to experimental procedure, 100 series of 5 visual stimuli were presented during each experimental session. The time required was about 20 minutes. For F. and W., there were presented 50 of the click-series and 50 of the clickless series. These series of 50 were alternated in time at the different experimental sessions, the latter falling on different days. There was a recess between the 'fifties' of 2½ minutes duration. Each of the four observers was presented with 200 series of 5 stimuli each, and each made a total of 1,000 judgments. Two series of 5, or 10 stimuli, in Series 1 were accidentally omitted in the case of observer N. This omission was neglected in computing the results of rows 4 and 5, Series 1, in the body of Table XXI; which makes no significant difference.

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[47] See footnote 45, p. 63.

During the recess between the halves of the experimental sessions, a negative after image of the whole field was frequently observed by directing the eyes to a grey screen 50 cm. distant. It faded out in an average time of about one minute and thirty seconds from the conclusion of stimulation; and was consequently not present at the commencement of the second half of the session.

The data of Series 1 are arranged to show, comparatively, the percentage 'Yes' (stimulus superthreshold) judgments corresponding to each of the five stimulation-times; that is, to show the percentage of stimuli falling on the first second judged superthreshold, the percentage falling on the second judged superthreshold, and so on. Since the observer was given no auditory signals, except the ready signal, in Series 2, he could not report the time-categories of his judgments; that is, he could not designate them numerically. The data of Series 2 consequently only contain totals.

The results of this group are given in Tables XIX-XXIII. The results for each observer are given in a separate table. Tables XIX-XXII are of similar arrangement; the first horizontal row across the top of each gives the series, and the second row gives both the numbers of the seconds on which the Series 1 stimuli fall; and the 'Total' heading for each series. The vertical columns under these various headings contain the corresponding results. The first horizontal row of the body of the table contains the numbers of stimuli presented, that is, 100 on each of the five successive seconds. Only the total, 500, is given for Series 2, for reasons above given. The second row contains the numbers judged superthreshold, and the third the corresponding percentages, where not obviously given in the second row. The fourth row gives, for each second, the mean variation of the average number superthreshold of 5 groups of 20 stimuli each. The averages themselves are based on a division of the 100 stimuli falling on each second into 5 groups, according to their original time-order. It is not possible to give a mean variation for Series 2, because the time-categories of the judgments are unknown, making it impossible to compute averages corresponding to those of Series 1, upon which the mean variation under 'Total' is necessarily based. The fifth row contains the averages of the estimated brightnesses. These averages are based on the numbers of superthreshold cases which are given in the second row above. The sixth row gives the corresponding mean variations. In Table XXIII, the first horizontal row across the top gives the series, while the second row gives the *experimental days* or *sessions*. The two upper horizontal rows of the body of the table contain results for observer D., and the two lower rows the same for observer N. Otherwise, the table seems self-explanatory.

Brightness judgments of five successive stimuli made on the one hand when attention was aided by a simultaneous auditory signal (Series 1), and on the other hand when attention was not so aided (Series 2).

TABLE XIX
Observer D

	Series 1 Experimental						Series 2 Control
	1″	2″	3″	4″	5″	Total	Total
No. of Stimuli	100	100	100	100	100	500	500
No. Superthreshold	74	82	89	88	88	421	247
% Superthreshold						*84*	*49*
M. V. (in % of Av.*)	18	17	6	12	10	13	
Av.Estimated Brightness	1.3	1.2	1.2	1.2	1.1	*1.2*	*.73*
M. V. (in % of Av.*)	39	36	33	34	34	35	38

TABLE XX
Observer F

	Series 1 Experimental						Series 2 Control
	1″	2″	3″	4″	5″	Total	Total
No. of Stimuli	100	100	100	100	100	500	500
No. Superthreshold	96	98	99	99	99	491	497
% Superthreshold						*98*	*99*
M. V. (in % of Av.*)	2.3	2.4	1.6	1.6	1.6	2.6	
Av. Estimated Brightness	.67	.68	.68	.69	.69	*.68*	*.76*
M. V. (in % of Av.*)	35	37	39	38	36	37	43

Brightness judgments of five successive stimuli made on the one hand when attention was aided by a simultaneous auditory signal (Series 1), and on the other hand when attention was not so aided (Series 2).

TABLE XXI
Observer N

	Series 1 Experimental						Series 2 Control
	1″	2″	3″	4″	5″	Total	Total
No. of Stimuli	98	98	98	98	98	490	500
No. Superthreshold	69	68	66	71	82	356	243
% Superthreshold	70	69	67	72	84	*73*	*49*
M. V. (in % of Av.*)	16	9	11	16	6	14	
Av. Estimated Brightness	.97	.97	.95	.92	1.1	*.98*	*.34*
M. V. (in % of Av.*)	69	74	76	65	55	40	40

TABLE XXII
Observer W

	Series 1 Experimental						Series 2 Control
	1″	2″	3″	4″	5″	Total	Total
No. of Stimuli	100	100	100	100	100	500	500
No. Superthreshold	37	46	64	79	84	310	254
% Superthreshold						*62*	*51*
M. V. (in % of Av.*)	34	15	14	9	6	29	
Av. Estimated Brightness	.66	.65	.60	.57	.60	*.61*	*.55*
M. V. (in % of Av.*)	36	34	27	22	27	29	16

*This average is average number superthreshold of 20 stimuli in 5 groups.

TABLE XXIII
Data arranged to expose negative practice effect for observers D. and N., in whose cases Series 1 temporally preceded Series 2

	Series 1						Series 2					
Exp'l Day	1	2	3	4	5	Total	1	2	3	4	5	Total
D												
No. Superthreshold	70	89	95	84	83	421	78	44	46	54	25	247
Av.Est.Brightness	1.2	1.4	1.3	1.1	.86	1.2	.79	.64	.73	.75	.64	.73
N												
No. Superthreshold	88	67	70	64	67	356	40	43	59	51	50	243
Av.Est.Brightness	1.6	1.3	1.3	1.3	1.1	1.3	.65	.76	.75	.67	.65	.70

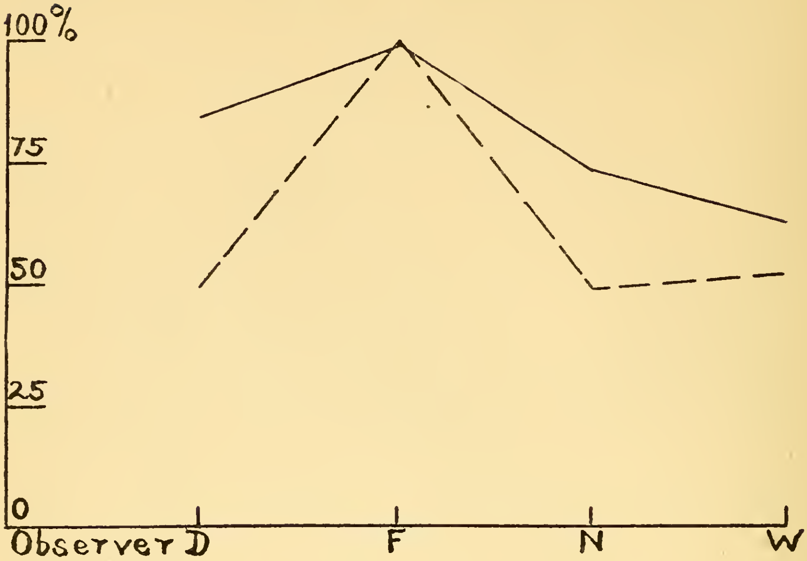

Fig. 12

Fig. 12 summarily exhibits the data for D., F., N., and W. under 'Totals' in the third horizontal row of the bodies of Tables XIX-XXII; and shows the tendency for an increased number of visual stimuli to be judged superthreshold when there are simultaneously presented auditory stimuli. There is a separate curve for each series; for Series 1., that is, when the auditory stimuli were given, it is a solid line; while for Series 2 it is a broken line.

RESULTS OF GROUP II

1. Comparison of the 'per cent superthreshold' in the 'Total' columns of Series 1 and 2, in each of the first four tables, shows that for observers D., N. and W. there were significantly more stimuli judged superthreshold when the simultaneous auditory stimuli were given (Series 1) than otherwise (Series 2). For F., on the other hand, there were very slightly less stimuli judged superthreshold when the auditory stimuli were used. There is consequently a tendency for the auditory stimuli to be accompanied by an increased number of visual stimuli judged superthreshold. These results are exhibited graphically in Fig. 12.

2. Detailed study of the second and third horizontal rows of Series 1 reveals that there is a tendency for the number of stimuli judged superthreshold to increase toward the end of

the series of five successive stimuli.[48] This tendency is in harmony with our early speculation which led to the making of these experiments.

3. The fourth row of Series 1 indicates a tendency for the mean variation to decrease toward the end of the series of five stimuli.

4. Comparison of the average estimated brightnesses in the 'total' columns for Series 1 and 2 throughout, shows that they are larger, for each observer except F. (again), when the auditory stimuli are given than otherwise. See Fig. 13.

5. The fifth row of Series 1 shows a slight tendency for the average estimated brightness to decrease toward the end of the series of five successive stimuli.

6. Detailed study of Table XXIII shows that for observers D. and N., in whose cases the series with the clicks preceded that without the clicks, there is in general a negative practice effect. The differences in the totals must consequently be regarded as somewhat too large.

SUMMARY OF RESULTS WITH INTERPRETATIONS FOR VISUAL EXPERIMENTATION

The principal results under the experimental conditions are:

1. When an approximately difference-liminal, momentary, visual stimulus is presented, variously, after three different prestimulus situations, the number of stimuli judged superthreshold, that is, the number of observed brightnesses, has

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[48] In certain visual experiments McDougall was enabled to compare two momentary successive brightnesses by means of a rotating disc with two diametrically opposed sectorial openings which successively passed the light source. The areas of the openings and so the brightnesses could be independently varied. He remarked that "frequently I did not perceive the difference of brightness of the two flashes first seen, and often did not feel certain of the alternation of brighter and duller flashes until they had been repeated several times." "Perception of the small differences of brightness of the momentary flashes demands accurate accommodation of the eye and a favorable setting of the expectant attention for each flash." McDougall, W.: The variation of the intensity of visual sensation with the duration of the stimulus. Brit. Jour. Psychol., June, 1904-5, I, 165.

Stimulating a single eye foveally, in the dark room under dark adaptation, Rutenburg noticed that light-flashes which were subthreshold because of low intensity and duration, became superthreshold when repeated with a time-interval of 1.5 seconds or less. The duration of the minimal flash varied from 6.2 to 13.2 sigma. Rutenburg, D.: Ueber die Netzhautreizung durch kurzdauernde Lichtblitze und Lichtlücken. Zeit. f. Sinnesphysiol., 1914, 48, 279 ff.

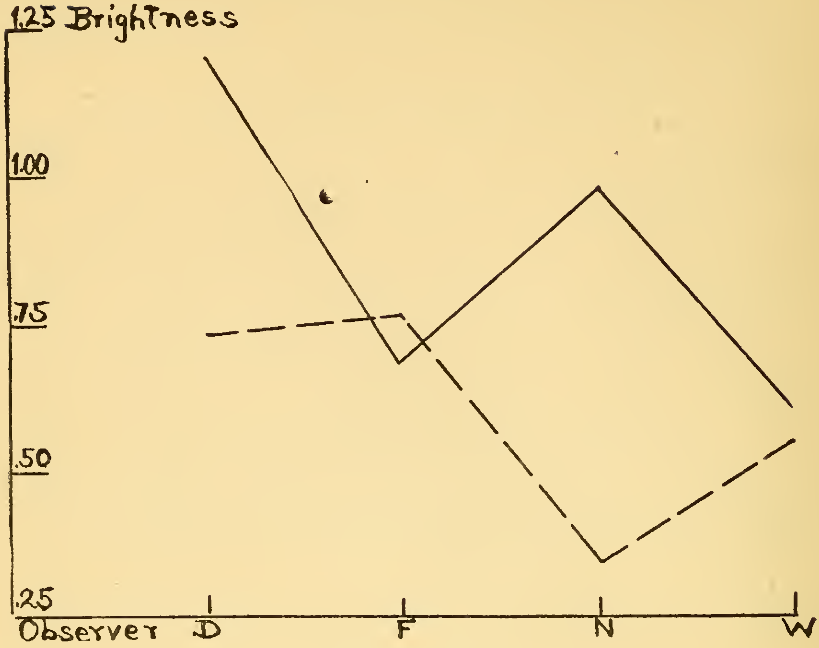

Fig. 13

Fig. 13 summarily exhibits the data for D. F., N., and W. under 'Totals' in the sixth horizontal row of the bodies of Tables XIX-XXII, and shows the tendency for the average estimated brightness to be larger when there are simultaneously presented auditory stimuli than otherwise. There is a separate curve for each series; for Series 1, that is, when the auditory stimuli were given, it is a solid line; while for Series 2 it is a broken line.

somewhat of a tendency to vary with the prestimulus situation. (Table XVIII.)

As a result of the different prestimulus situations, the observer apparently tends to receive the stimulus under correspondingly different degrees of attention, so that there may perhaps be said to be somewhat of a tendency for the number of stimuli judged superthreshold to vary with the degree of attention;[49] but the numerical results do not justify a more positive statement.

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[49] McDougall found that when successive flashes were presented one second apart (by means of disc apparatus (p. 160 or our footnote 48) either could be made brighter "by voluntarily setting the attention." He writes as follows: "It might be supposed that when the impressions N and W were of equal intensity it would be impossible to arrive at a judgment of inequality, but such was not the case. I found that the setting of the expectation sufficed then to cause either one to appear brighter, so that by voluntarily setting the attention for the alternation bright-dull, either N or W could be made to appear slightly brighter." Op. cit., 166-7. Also, cf. footnote 36, p. 44.

2. There is a tendency for the momentary visual brightness to vary in degree according to the prestimulus situation, and so as above we believe, according to the degree of attention. (Table XVIII.)

The fact that there is a certain tendency for both the number of stimuli judged superthreshold and the degree of momentary brightness to vary with the prestimulus situation, and so in the direction of the more favorable attentional conditions, points toward increases of magnitude paralleling increases of attention.[50]

3. If series of five momentary visual stimuli whose physical value is uniform and approximately at the difference-limen, are presented simultaneously with five clicks, there is tendency for more of the visual stimuli to be judged superthreshold than in series where the clicks are omitted. (Tables XIX-XXII).

Introspective evidence and the conditions of stimulation seem to indicate that the serial rhythm or periodicity established by the clicks and their signal value regarding the times of stimulation, are significant concomitants of the increase in number of superthreshold judgments. That these concomitants, however, are *factors* in a higher attention, the latter being the more immediate reason for the greater number of superthreshold judgments, is a suggested interpretation.

4. When the auditory clicks are presented simultaneously with the visual stimuli there is a tendency for the number of visual stimuli judged superthreshold to increase toward the end of the series of five successive stimuli. (Tables XIX-XXII).

This tendency harmonizes with the interpreted significance of the periodicity established by the clicks to the number of stimuli judged superthreshold. Still, we have no proof that it is not a result of ordinary peripheral adjustment.

5. The totals of the estimated brightnesses tend to be larger when the clicks are given than when they are omitted. (Tables XIX-XXII).

As in results (1) and (2) obtained by a different method, so here in results (3) and (5) there is exhibited the dual tendency to judge more stimuli superthreshold and of greater magnitude when presented under the more favorable attentional conditions.[51]

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[50] Some of this may be due to retinal fatigue on grounds mentioned by Troland. Preliminary note: the influence of changes of illumination upon after-images. Am. Jour. Psychol., 1917, 28, 497-503, esp. 500, 503.

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[51] "While our results are apparently ascribable to attention, we must note that after experimenting with sensory suggestion in which the "suggestion . . . ran counter to the facts," Edwards writes that "we do not hesitate to draw the conclusion that, in certain departments of sense (including vision and probably touch), a verbal suggestion may arouse conscious processes which are, phenomenologically identical with those ordinarily aroused by an adequate stimulus or change of stimulus." (128-9) The suggestion was surprisingly potent even "in the case of observers who had frankly avowed suspicion." Two observers frequently "accepted" suggestions "against which they were, in general, on guard." (116, 129) Verbal suggestion that the colorless visual stimulus was 'brighter,' frequently evoked a 'brighter' judgment even though the stimulus was made physically darker. Also vice versa. (113-117) Results were reported as different from what was expected. (116, 129). Cf. Edwards, A. S.: An Experimental Study of Sensory Suggestion. Am. Jour. Psychol., 1915, 26, 99-129.

IV. CONCLUSIONS AND THEORETICAL CONSIDERATIONS

Without recapitulating in detail the results and interpretations of the pressure (pp. 45-46) and the visual (pp. 69-71) experiments; we may apparently conclude in general, that attention increases the intensity of moderate and liminal areal pressures, and the degree of moderate visual brightness when near the difference-limen. The results in both sense-fields seem to indicate that on the one hand attention increases the number of stimuli which are superthreshold, and on the other hand, that attention increases the intensity of pressure and the degree of brightness of the respective stimuli when they *are* superthreshold.

According to Fechner, increase in the number of superthreshold stimuli would not necessarily mean an intensive increase.[52] If this were so, results merely showing that attention can raise a subthreshold stimulus above the threshold would be of no intrinsic value in the support of our conclusion. It is not considered so, however, because it seems reasonable that if a subthreshold stimulus rises above the threshold, the intensity of the sensation must rise from zero to some intensity.

While an aim in this paper has been to keep the content exclusively experimental, as far as possible, it is interesting to see in how far results apparently bearing on the thesis will fit into a plausible theoretical structure. The significant results from both sense-fields may first be combined as follows: (1) There is a tendency to judge the content more intensive under the more favorable attentional conditions; (2) There is a tendency to judge more stimuli superthreshold under the more favorable attentional conditions; (3) The mean variation of the number of superthreshold cases is smallest under the most favorable attentional conditions;[53] (4) Depressed respiration apparently lowers the pressure threshold; (5) In Group II of the pressure experiments (cf. Table XIII, p. 33), the distribution of true and false cases is roughly the same for each observer, but the distribution of over and underestimates differs widely; (6) The mean variation of the brightness is highest under the most favorable attentional conditions (cf. Table XVIII, p. 59).

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[52] Elemente der Psychophysik., Leipzig, 1860, Bd. ii, 452-3. Revision der Hauptpunkte der Psychophysik., Leipzig, 1882, 272.

[53] Measuring attention in terms of clearness values, Geissler found a very close parallelism between degree of attention and corresponding precision of work performed. Op. cit., 502-529.

An approximately liminal stimulus of fixed value is assumed, while the height of the limen is assumed to vary in some inverse relation to the degree of attention. Then, if the degree of attention were low the limen would be high, that is, the stimulus would be subthreshold; and if the degree of attention were high the limen would be low, that is, the stimulus would be superthreshold. Similarly, some intermediate degree of attention would give rise to a mean limen and so a threshold stimulus.

In experimentation near the limen the number of stimuli judged superthreshold, other things equal, tends to vary directly with the intensity. But if the intensity of the stimulus is fixed and the height of the limen varied, it follows that the number of stimuli judged superthreshold will tend to bear some inverse relation to the height of the limen.

In our liminal experiments the stimulus-value was fixed, while the number of superthreshold stimuli seemed to vary with the degree of attention, that is, the limen tended to vary inversely with the degree of attention. In other words, attention appeared to lower the limen, which may be synonymous with increasing the intensity. A lowering of the limen, then, would seem to account for the first two results above. With regard to the third result, the lower the threshold the smaller would the mean variation of the number of superthreshold cases tend to be (if the stimulus is perceived most of the time); because with the low threshold there would be the increased probability of the observer experiencing all the stimuli, that is, nearer approach to zero mean variation. Fourth, depressed respiration is a characteristic accompaniment of voluntary attention and if consequently regarded as an attentional factor, then a lowered limen because of it may occur under attention. It seems to be true, however, because of the introspections and the various experimental procedures, that most of the results indicating increased intensity due to attention are not paralleled by changes in respiration-amplitude. Fifth, the wide variation among observers in the distribution of the over- and under-estimations, while the distribution of the true and false cases remained about the same, seems in harmony with the characteristic instability of high attention. Sixth, the increased mean variation of brightness under favorable attentional conditions can apparently be explained on the ground that the limen is, *in general,* lower, and that consequently there is more *possibility* of variation in the brightness (for the degree of estimated brightness is most always low, i. e., less than half the maximal brightness). High attention is characteristically unstable and hence the limen would be unstable, and the observed brightnesses would vary from the maximum with high attention to minimum with slips of attention.[54]

As regards a theory of attentional intensification in the ordinary sense, that is, a physiological explanation or nervous correlation, we have nothing new to offer. Our results point to a facilitation or reinforcement process, and it does not seem useful in this instance to substantially reiterate or to add to the relevant theories already pronounced.[55]

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[54] Cf. Peters in this connection, op. cit., 423-7.

[55] For references to facilitation and reinforcement theories see, Newhall, op. cit., 226-7. Cf., Boring, references and text, op. cit., 79, 87-8, 93. In the light of v. Frey's remarks it seems improbable that our pressure results are affected by or due to the fusion, facilitation, or inhibition reported as operating between pressures whose spatial separation is not great. "At great distances as for example between the right and left hand . . . they (verstärkend, verdeckend, anziehend) are not demonstrable." (597) The intensifying activity occurs up to 12 cm. separation but not beyond, apparently. (583) Cf., v. Frey: Die Wirkung gleichzeitiger Druckempfindungen aufeinander. Zeitschrift für Biologie, 1911, 56, 574-598. Also v. Frey; Die Einwirkung einfacher Druckempfindungen aufeinander. Bericht über den IV Kongress f. exp'telle Psychol. in Innsbruck u. s. w., Leipzig, 1911, S. 233.

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